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AXBT OBSERVATIONS OF TROPICAL PACIFIC OCEAN THERMAL STRUCTURE D--ETC(U)  
SEP 78 W C PATZERT, T P BARNETT, M H SESSIONS N00014-75-C-0152  
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## AXBT Observations of Tropical Pacific Ocean Thermal Structure During the NORPAX Hawaii / Tahiti Shuttle Experiment November 1977 to February 1978

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### SIO REFERENCE SERIES

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Prepared for  
NATIONAL SCIENCE FOUNDATION  
as part of the North Pacific Experiment  
under grant OCE 70-00103  
with support from  
OFFICE OF NAVAL RESEARCH  
and

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

SEPTEMBER 1978

University of California

Scripps Institution of Oceanography  
REFERENCE #78-24

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AXBT OBServations of Tropical Pacific Ocean Thermal Structure During the NORPAX Hawaii/Tahiti Shuttle Experiment 11/77-2/78		5. TYPE OF REPORT & PERIOD COVERED
7. AUTHOR(s) William C. Patzert Tim P. Barnett Meredith H. Sessions Bernard Kolonsky/Univ. of Hawaii		6. PERFORMING ORG. REPORT NUMBER 78-24
9. PERFORMING ORGANIZATION NAME AND ADDRESS  Scripps Institution of Oceanography La Jolla, CA 92093		8. CONTRACT OR GRANT NUMBER(s) N00014-75-C-0152 OCE 76-80183
11. CONTROLLING OFFICE NAME AND ADDRESS  Office of Naval Research Arlington, VA 22217		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE September 1978
		13. NUMBER OF PAGES 61
		15. SECURITY CLASS. (of this report)  Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release: distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)  see page 1		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) From November to February 1978, thirteen round trips were flown aboard P-3 airplanes between Hawaii/Tahiti. The primary measure- ment program aboard these flights was the collection of air- ex- pendable bathythermography (AXBT) data along N/S flight tracks between 20°N and 17°S. Although flights were made as often as every day for one week, the usual temporal sampling was once per week. A three-month time series of sixteen temperature sections..		

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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(12)

University of California, San Diego  
Scripps Institution of Oceanography  
La Jolla, California

(15) NP0014-75-C-0152, NSF-OCE 76-80183

(6) AXBT OBSERVATIONS OF TROPICAL PACIFIC  
OCEAN THERMAL STRUCTURE DURING THE  
NORPAX HAWAII/TAHITI SHUTTLE EXPERIMENT  
NOVEMBER 1977 TO FEBRUARY 1978

by

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(14) SIO-REF-78-24

NORTH PACIFIC EXPERIMENT

Sponsored by NSF-

National Science Foundation Grant OCE 76-80183

with support from (15) NSF-OCE 76-80183

The Office of Naval Research  
and  
National Oceanic and Atmospheric Administration

SIO Reference 78-24

(11) September 1978

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# Abstract

From November <sup>1977</sup> to February 1978, thirteen round trips were flown aboard P-3 airplanes between Hawaii/Tahiti. The primary measurement program aboard these flights was the collection of air-expendable bathythermograph (AXBT) data along N/S flight tracks between 20°N and 17°S. Although flights were made as often as every other day for one week, the usual temporal sampling was once per week. A three-month time series of sixteen temperature sections was obtained along 150°W and a two-month series of ten sections was gathered from 158°W.

This preliminary report displays the AXBT data collected during the P-3 flights. The text describes the methods and instrumentation used to collect the data, data processing, and finally the data display. Included are graphical presentations of each temperature section and various derived time series and statistical fields.

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## 1.0 Introduction

Long-range P-3 aircraft were used for three months (November 1978 through February 1979) to rapidly sample the upper ocean thermal structure along 150° and 158°W in the central Pacific between Hawaii and Tahiti. The aircraft measurement program consisted primarily of collection of air expendable bathythermograph (AXBT) data along N-S flight tracks. The objective of this program was to describe and quantitatively explain the observed temporal and spatial fluctuations in the upper 300 m of the oceanic thermal field.

The development of this field work began when the FGGE (First GARP Global Experiment) was proposed for 1979-80. North Pacific Experiment (NORPAX) scientists recognized this as a unique opportunity to obtain excellent wind stress data and other atmospheric data sets to compare with changes in equatorial ocean circulation (Wyrski et al., 1977). In preparation for FGGE, NORPAX scientists began during the winter of 1977-78 with a three-month pilot experiment intended to develop and refine measurement techniques for use in 1979-80, and to obtain preliminary information on spatial and temporal scales of oceanic variability (Patzert et al., 1978). The analysis of these data sets will be used to design rational sampling schemes for the larger, longer experiment during FGGE. Proceeding with this stepwise plan, we are optimistic that the understanding of



low-frequency, large-scale ocean/atmosphere interaction will be achieved and that this understanding will be a substantial aid in short-term environmental forecasting.

This preliminary report displays the data collected from November 1978 to February 1979. It is hoped that visual inspection of this data by various investigators will interest them in the scientific problem at hand, as well as providing a feeling for how the ocean actually changes over large space and time scales. With this present limited objective, the text will do nothing more than present the data. Little, if any, explanation will be offered as to the mechanism causing the observed changes. Therefore, the following sections of the text describe briefly the methods and instrumentation used to collect the data, data processing, and finally the data display. The graphical presentation of each temperature section and the resulting derived time series and statistics make up the body of the report.

## 2.0 Methods

### 2.1 Operations

The standard operation called for occupying each section approximately every week. A preliminary sampling, however, was conducted along the 150°W to investigate high-frequency variability. The data-gathering exercise

TABLE 1

Schedule of P-3 Aircraft Flights during the Pre-ECGE NORPAX Equatorial Experiment  
 along 150°W (16 flights from 5 Nov. 77 to 30 Jan. 78) and  
 along 158°W (10 flights from 1 Dec. 77 to 1 Feb. 78)

Flight Number	Date of Flight	Consecutive Days from Flight #1	Longitude of Flight (°W)	Direction of Flight	Aircraft Used for Flight	Flight Mission
1	5 Nov.	1	150	* H to P	+ USNR VP-91	Shakedown flights
2	9 Nov.	5	150	** P to H	USNR VP-91	along 150°W
3	16 Nov.	12	150	H to P	USNR VP-60	4 burst samples along 150°W
4	18 Nov.	14	150	P to H	USNR VP-60	
5	20 Nov.	16	150	H to P	USNR VP-91	
6	22 Nov.	18	150	P to H	USNR VP-91	
7	29 Nov.	25	150	H to P	<sup>T</sup> NOAA WP-3D	6 weekly NOAA flights down 150°W and up 158°W
8	1 Dec.	27	158	P to H	NOAA WP-3D	
9	6 Dec.	32	150	H to P	NOAA WP-3D	
10	8 Dec.	34	158	P to H	NOAA WP-3D	
11	13 Dec.	39	150	H to P	NOAA WP-3D	
12	15 Dec.	41	158	P to H	NOAA WP-3D	
13	20 Dec.	46	150	H to P	NOAA WP-3D	
14	22 Dec.	48	158	P to H	NOAA WP-3D	
15	27 Dec.	53	150	H to P	NOAA WP-3D	
16	29 Dec.	55	158	P to H	NOAA WP-3D	
17	3 Jan.	60	150	H to P	NOAA WP-3D	Flights down 150°W and up 158°W
18	5 Jan.	62	158	P to H	NOAA WP-3D	
19	10 Jan.	67	150	H to P	USNR VP-61	
20	12 Jan.	69	158	P to H	USNR VP-61	
21	14 Jan.	71	150	H to P	USNR VP-90	
22	16 Jan.	73	158	P to H	USNR VP-90	
23	24 Jan.	81	150	H to P	USNR VP-69	
24	26 Jan.	83	158	P to H	USNR VP-69	
25	30 Jan.	87	150	H to P	<sup>Y</sup> NOO VNX8	
26	1 Feb.	89	158	P to H	NOO VNX8	

\* H to P = Honolulu to Papeete

\*\* P to H = Papeete to Honolulu

+ USNR = United States Naval Reserve

<sup>T</sup> NOAA = National Oceanic and Atmospheric Administration

<sup>Y</sup> NOO = Naval Oceanographic Office

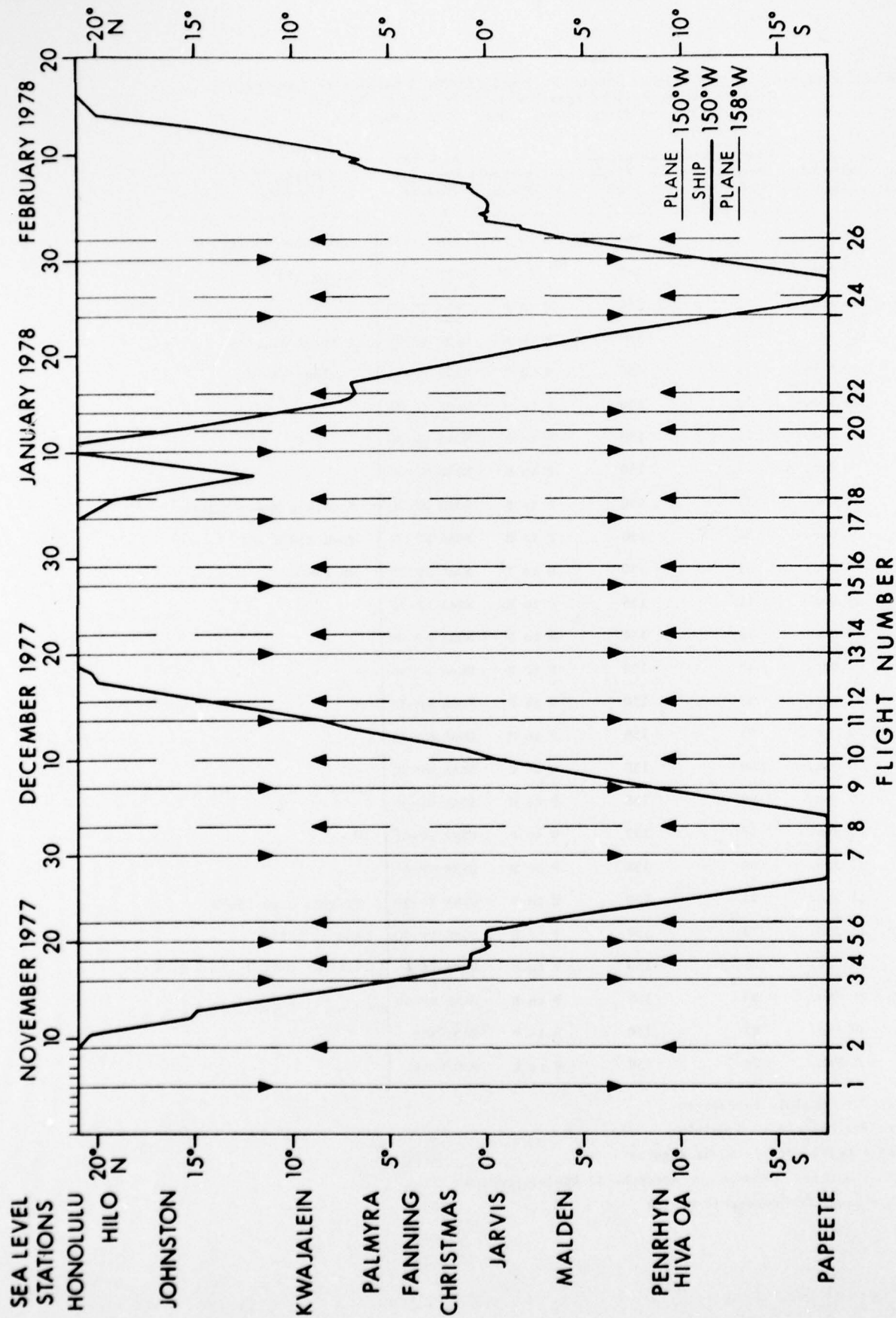


Figure 1. The schedule of P-3 aircraft flights and the cruise track of the R/V KANA KEOKI during the NORPAX Pre-FGGE Shuttle Experiment. The approximate latitudes of the mid-Pacific sea level stations are shown to the left.



began in Honolulu. From there the U.S. Navy Reserve P-3 flew to coordinates 20°N, 150°W and then south along the 150th meridian. Similar flights were also made by NOAA P-3's and a P-3 associated with the Naval Oceanographic Office (see Table 1 for the flight schedule). AXBT's (see below) were dropped at approximately 1° (110 kilometer) intervals between 20°N and 17°S. In the region between 14°N and 6°S the BT's were spaced at 1/2° latitude (55 kilometer) separations. After the final drop at 17°S the plane landed in Tahiti for a day's layover and crew rest. From Tahiti the plane resumed the survey, flying to 16°S, 158°W and then north up the 158th meridian. AXBT's were again dropped on the 1° and 1/2° grid between 16°S and 20°N with the flight terminating in Honolulu. The study area and flight tracks are shown schematically in Figure 1. The data for individual flights are shown as Sections 1-26. Figures 2-17 show various statistical properties of these data and time series representations at the two meridians.

An on-board Scripps technician and scientist insured that the data were properly obtained during each flight. They were responsible for quality control as well as directing the general aspects of the flight. However, actual navigation, BT dropping, etc., were all done by the Navy or NOAA personnel and they proved most helpful.

## 2.2 Instrumentation

The airborne expendable bathythermograph (AXBT) was used to obtain a profile of temperatures as a function of depth. The instrument works in the following manner. The BT is launched from the aircraft at a predetermined location. Upon hitting the airstream a parachute deploys, slowing the BT's descent. Upon striking the surface of the water, an end-plate and parachute are jettisoned from the BT and it assumes the posture of a drifting spar buoy. With ejection of the parachute, an antenna is allowed to raise and, with the loss of the end-plate, the salt water activates a battery that eventually provides system power. Approximately two minutes after the BT has hit the water, a probe is released from the body of the buoy. The falling probe is connected to the buoy by a hard wire which returns temperature information to the still drifting surface float. Upon arrival in the surface float, the temperature information is used to modulate a radio carrier, with the resulting signal being received in the aircraft. The probe falls approximately 1.56 meters per second and continuously returns temperature data to a depth of roughly 330 meters. Approximately 7 minutes after the BT has entered the water, a scuttle plug is activated and the entire unit sinks.

The AXBT's being used in this operation have been calibrated such that their accuracy is easily within

+0.2°C. Details of the calibration procedure, characteristics of the probes themselves, etc., are reported elsewhere (Sessions et al., 1974, 1976; Barnett et al., 1976; and Sessions and Barnett, 1978). It turned out that the errors associated with the instruments were generally a factor of 10 less than the interannual variability experienced in the flight area and/or the variability observed over the course of the current experiment.

Another key component of the instrumentation used in this program was the navigation device used on the aircraft. A Litton inertial navigation system (LTN72) was used for each one of the flights aboard Navy aircraft. The accuracy of the system was checked after each flight and also during flights down the 150th meridian where a surface buoy, whose position was known from satellite positioning systems aboard ship, was overflown. During the flights with the NOAA aircraft, a dual inertial navigation system with an OMEGA update was used. In all cases the navigational capability of the aircraft was excellent. Hence we were able to go back to virtually the identical spot in the ocean time after time and re-drop an AXBT at that location. Errors in position of these drops were generally found to be less than 2 nautical miles. Thus changes in the thermal structure represented in the accompanying material are those resulting from changes in time rather than those induced by



inaccurate spatial sampling in a high-gradient field.

### 2.3 Data Recording

As stated above, the AXBT sends a VHF radio signal back to the plane. An audio frequency signal on the radio carrier can be converted to the desired information on temperature as a function of depth. Upon receipt the radio signal is routed from the aircraft radio system to a digital data logging system constructed at Scripps Institution of Oceanography (by Meredith Sessions). The data logger is highly versatile and provides the following features: Two independent cassette recorders provide redundant capability in digitizing incoming signal at one-second intervals, thereby providing a vertical temperature profile with 1.56-meter resolution. The data are digitized to the nearest  $0.03^{\circ}\text{C}$ , thus assuring that round-off errors are significantly less than calibration uncertainties associated with the BT itself. In addition to the two digital recorders, there is also a hard-copy printer that lists, at one-second intervals, the value of frequency stripped from the incoming radio signal. Perhaps most important, however, is a visual display (strip chart) of the observed temperature profile. It is this strip chart record that allows us to determine if the BT was a successful drop. BT failure (i.e., a failure to return a good signal at least through the mixed layer) requires that the aircraft return

to the last drop position and re-plant another AXBT. This on-site data inspection capability has allowed us to return well over 98% of the data that it would have been possible to collect. Hence the resulting data is virtually free of holes and gaps.

### 3.0 Data Processing

#### 3.1 Decoding and Error Checking

Immediately upon return to Hawaii following a flight, the cassette tapes were played through a Harris computer and converted to 9-track 800 BPI tape in a format that could be read by virtually any reasonable computer. During this translation process, header data were added and any peculiarities in the digital record, such as premature start of the data recording, a partial recording or bad AXBT, were deleted via an interactive terminal. Hence the tape that is generated is systematized in the sense that it can be read with a standard data editing program.

#### 3.2 Editing

Once the data had been converted into BCD characters it was read through an interactive data editing program on the Harris. Numerical peculiarities, if they did occur, were flagged automatically for study. Also, each AXBT trace is displayed on a cathode ray tube (CRT) and visually inspected

ror continuity and spikes which might exist in the data. Very few were ever found. However, several difficulties that did occur are listed below along with the manner in which they are handled.

- a) Sharp spike due to signal dropout in an otherwise smooth trace: The data point responsible for the spike was deleted and replaced with a value interpolated from either side of the missing point.
- b) A section of a trace unusable due to signal dropout: This difficulty usually occurred as the probe was reaching its depth limit. In this region the temperature profile is quite smooth. The editing treatment, therefore, is to delete the noisy section of the record and replace it with linear interpolation between the regions of good data on either side.
- c) Partial traces: It sometimes happened that the AXBT operated properly through the mixed layer (~100 meters) and then lost signal for some reason. In this case the remainder of the trace is set at 0 and no attempt is made at that time to interpolate from drops on either side.

The final data set that we developed from each section has thus been mechanically screened once and visually inspected twice for errors, incongruities, etc. Little, if

any, tampering with the data was ever required, so the resulting data set was extremely close to the data originally taken on the aircraft. The clean, complete data set was then forwarded to a large disk file on Control Data 7600 computer for scientific analysis.

#### 4.0 Data Display

##### 4.1 Individual Sections

Sections 1-16 are the data collected during individual flights along 150°W between 5 November 1977 and 30 January 1978. Sections 17-26 are along 158°W between 1 December 1977 and 1 February 1978. There are approximately 60 AXBT drops per section.

These sections were prepared almost entirely by computer, except the drawing of contours. Handwork also included drafting contours and the addition of contour labels.

##### 4.2 Variation of Thermal Structure

A primary goal of this experiment is to describe and quantify the variability in the upper ocean thermal structure. To provide a description of the variability observed along 150° and 158°W, sixteen figures have been prepared and included in this report. These figures should



provide a first-order picture of conditions present during the experiment.

Two mean sections (Figs. 2 and 4) have been prepared for the 150° and 158°W meridians. These sections are simply the averages of all AXBT data collected at a particular latitude along each meridian. From these mean sections, the mean vertical temperature gradient has been calculated for both meridians (Figs. 3 and 5). These mean fields provide a reference from which the variability observed can be gauged.

The short-term fluctuations in the thermal structure can be seen in Figure 6. The "burst" sampling done at two-day intervals for four flights along 150°W is indicated here. The total range of fluctuations of the 24°C and 14°C isotherms is shown in the next figure (Fig. 7). Figures 8 and 9 show the standard deviation of the thermal field as a function of depth and latitude at the two meridians.

Figures 10 through 17 are time series of the sea surface temperature, mixed-layer depth, depth of the 14°C isotherm (essentially the base of the main thermocline), and the thickness of the layer between 24° and 14°C (thickness of the thermocline) along 150° and 158°W during the experiment. These time series reveal that the sampling (both in time and space) quite adequately resolved the meso-

and large-scale variability that was present during the three month experiment.

A complete analysis of the AXBT data sets is presently underway and we will report on these results in the near future.

#### Acknowledgements

The National Science Foundation (NSF) supported the core proposal for the project organization, scientific/technical support, and data collection and processing. The Office of Naval Research (ONR) provided the 1615 Hermes AXBT probes used (we understand that this is the largest single experiment deployment of AXBTs ever made), arranged for the twelve U.S. Navy Reserve P-3 aircraft flights, and funded support for these flights and the rental of an LTN-72 inertial navigation system used aboard the Reserve P-3s. The National Oceanic and Atmospheric Administration (NOAA) dedicated their new P-3D aircraft to fly six weekly round trips during the middle of the experiment (split-funded by NSF). Finally, the U.S. Naval Oceanographic Office (N00) VXN-8 aircraft flew the final two flights to complete the observational program. We express our gratitude to NSF, ONR, NOAA and N00 for making our program possible and for their exceptional help and cooperation during the experiment. Also, a special kudo to

the Hermes Corporation for manufacturing excellent AXBTs. Approximately 95% of the AXBTs deployed functioned without problems.

A note of thanks also to Robert Lawson of the ONR branch in Pasadena, California. His attention to the many details and encouragement during the "darker hours" was crucial to our success.

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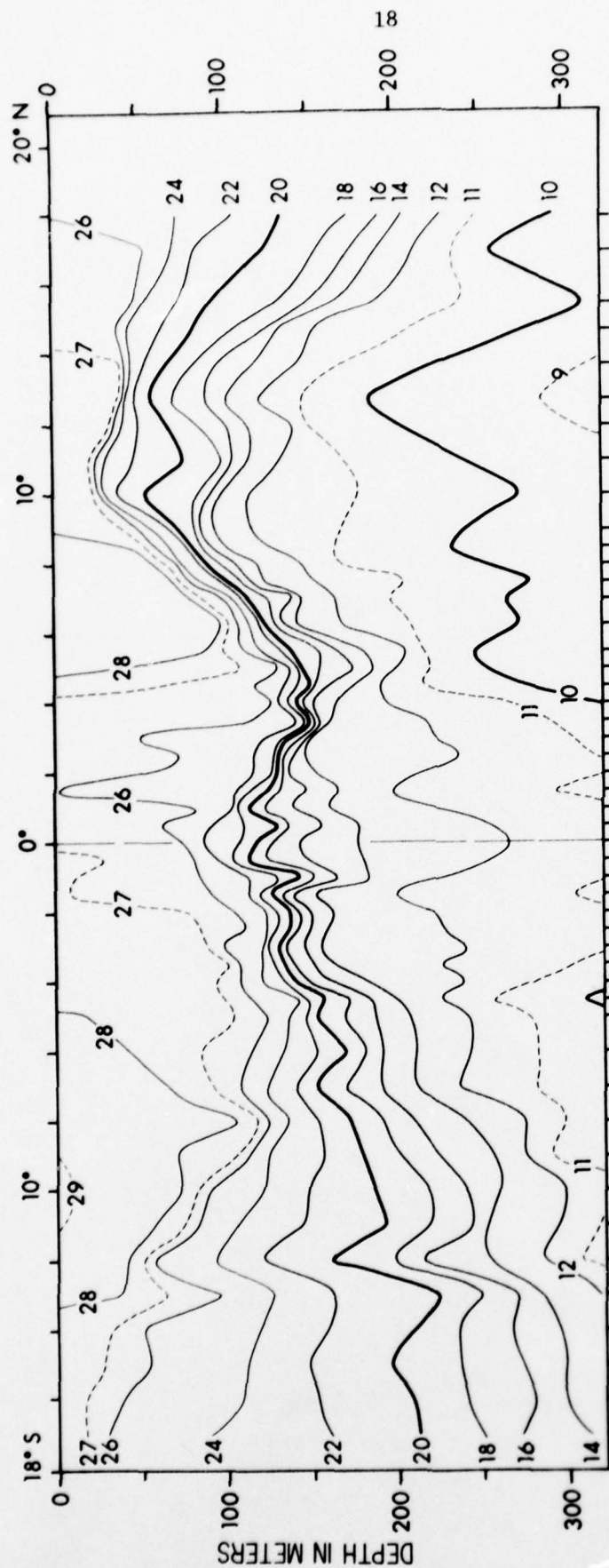


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Geophysics Report HIG-77-1.

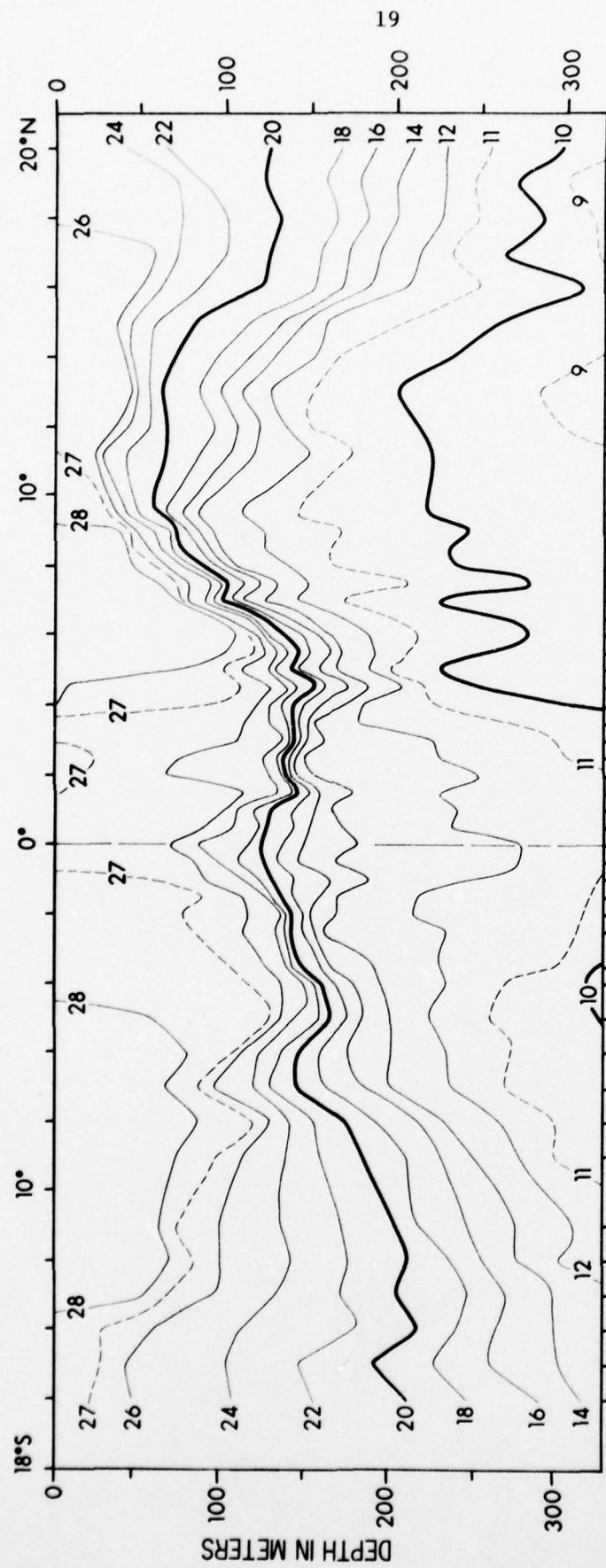
SECTIONS 1-16

150°W



# FLIGHT 1 150°W 5NOV.1977

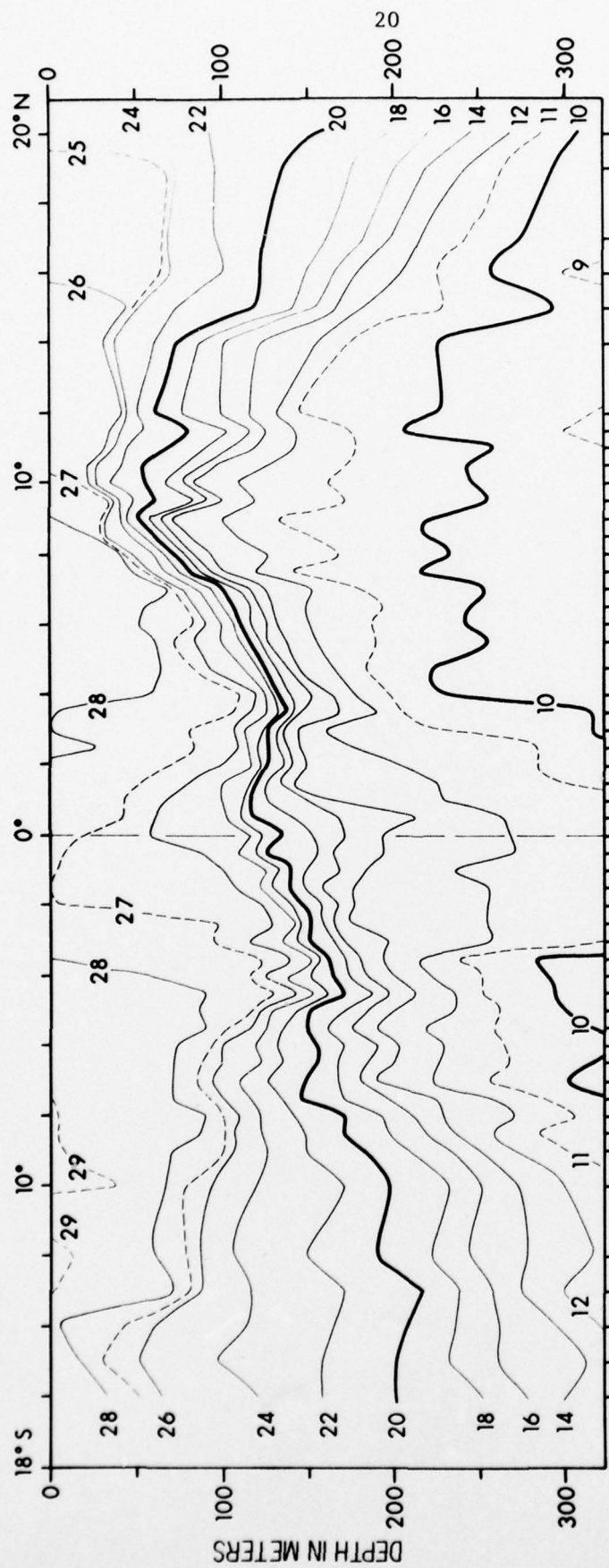
Section 1. Temperature in degrees centigrade along 150°W collected using AXBTs from a U.S. Navy Reserve P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



FLIGHT 2 150°W 9 NOV. 1977

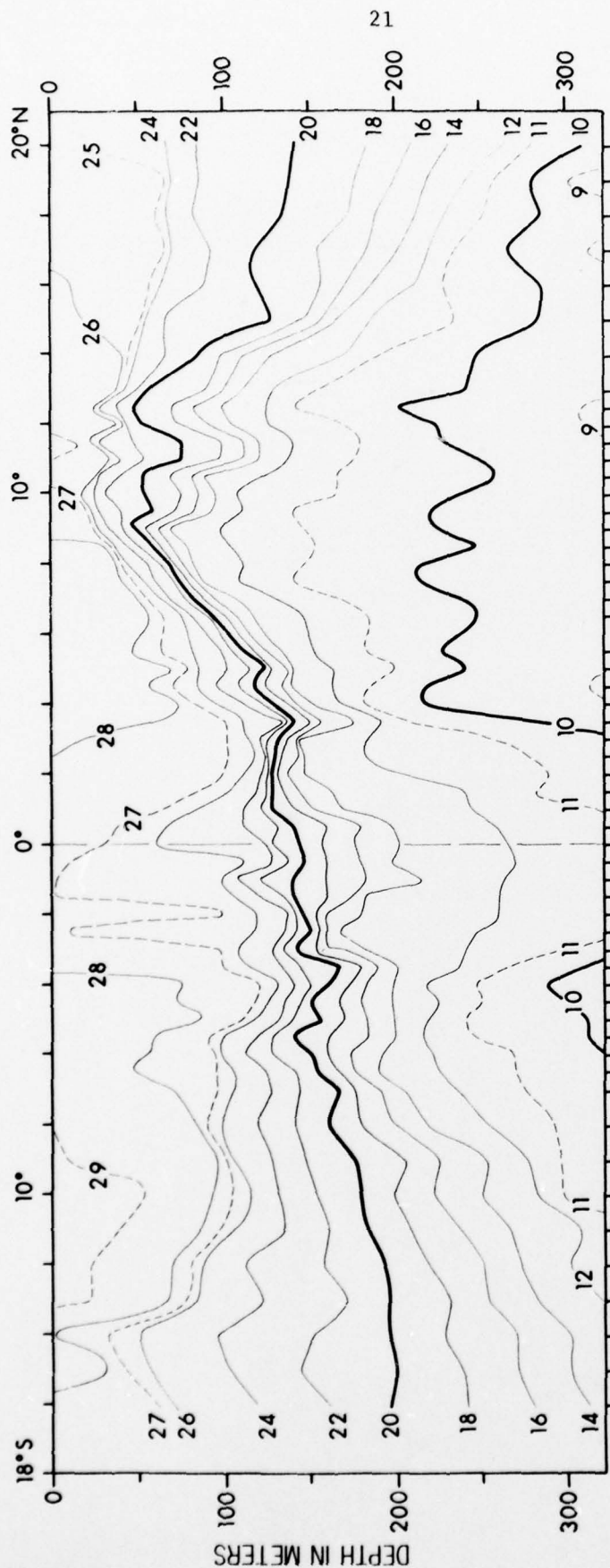
Section 2. Temperature in degrees centigrade along 150°W collected using AXBTs from a U.S. Navy Reserve P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.





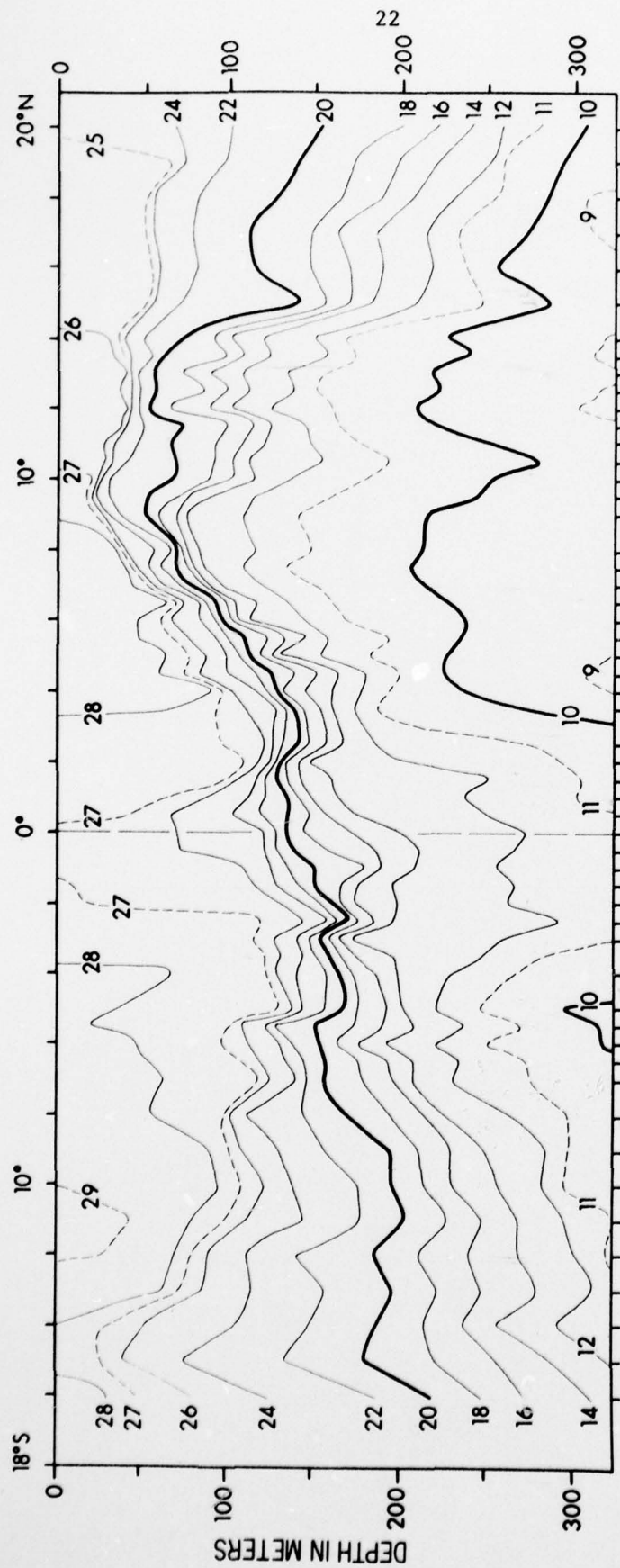
FLIGHT 3 150°W 16 NOV.1977

Section 3. Temperature in degrees centigrade along 150°W collected using AXBTs from a U.S. Navy Reserve P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



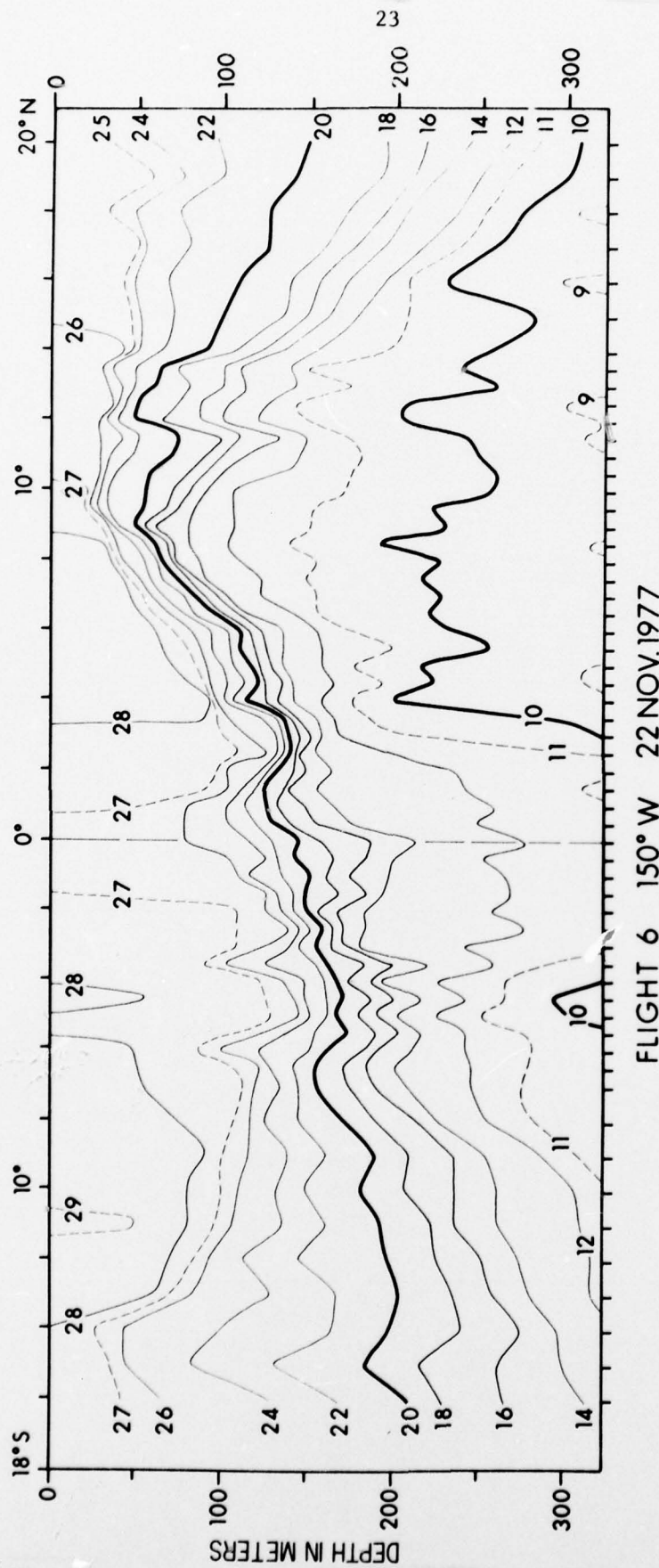
FLIGHT 4 150°W 18 NOV.1977

Section 4. Temperature in degrees centigrade along 150°W collected using AXBTs from a U.S. Navy Reserve P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



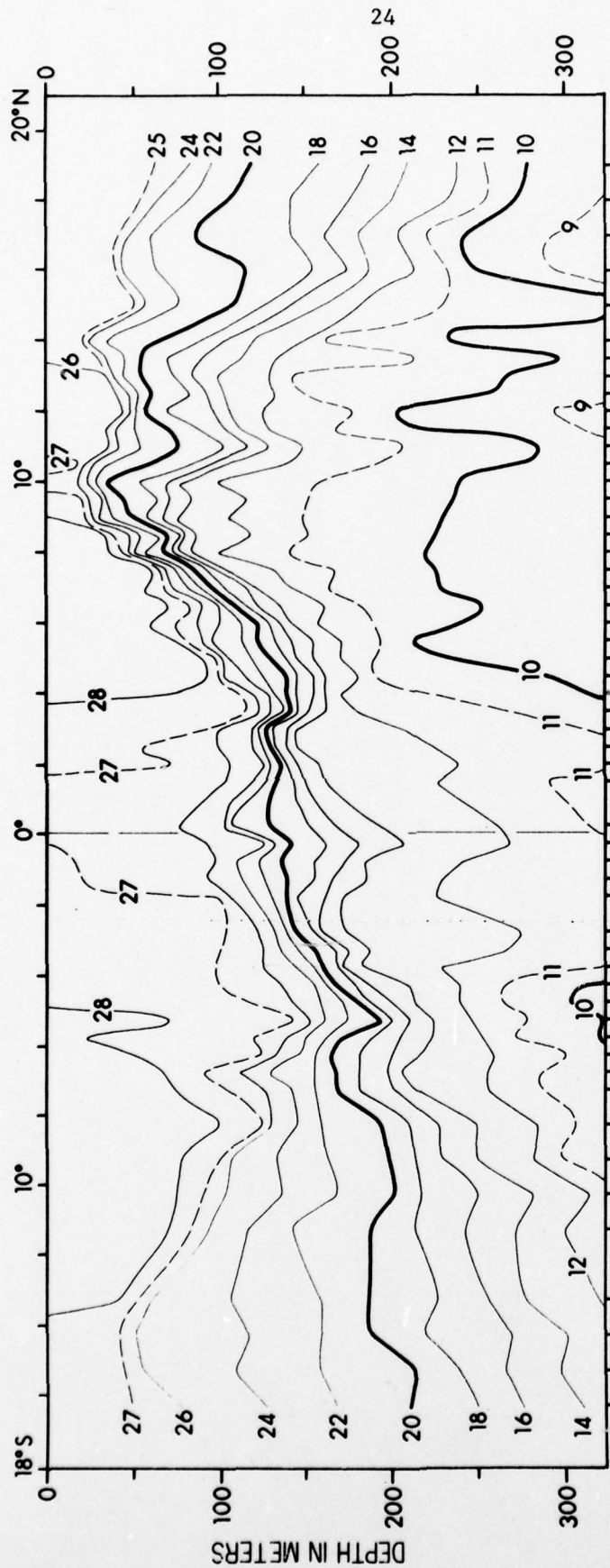
FLIGHT 5 150°W 20NOV.1977

Section 5. Temperature in degrees centigrade along 150°W collected using AXBTs from a U.S. Navy Reserve P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



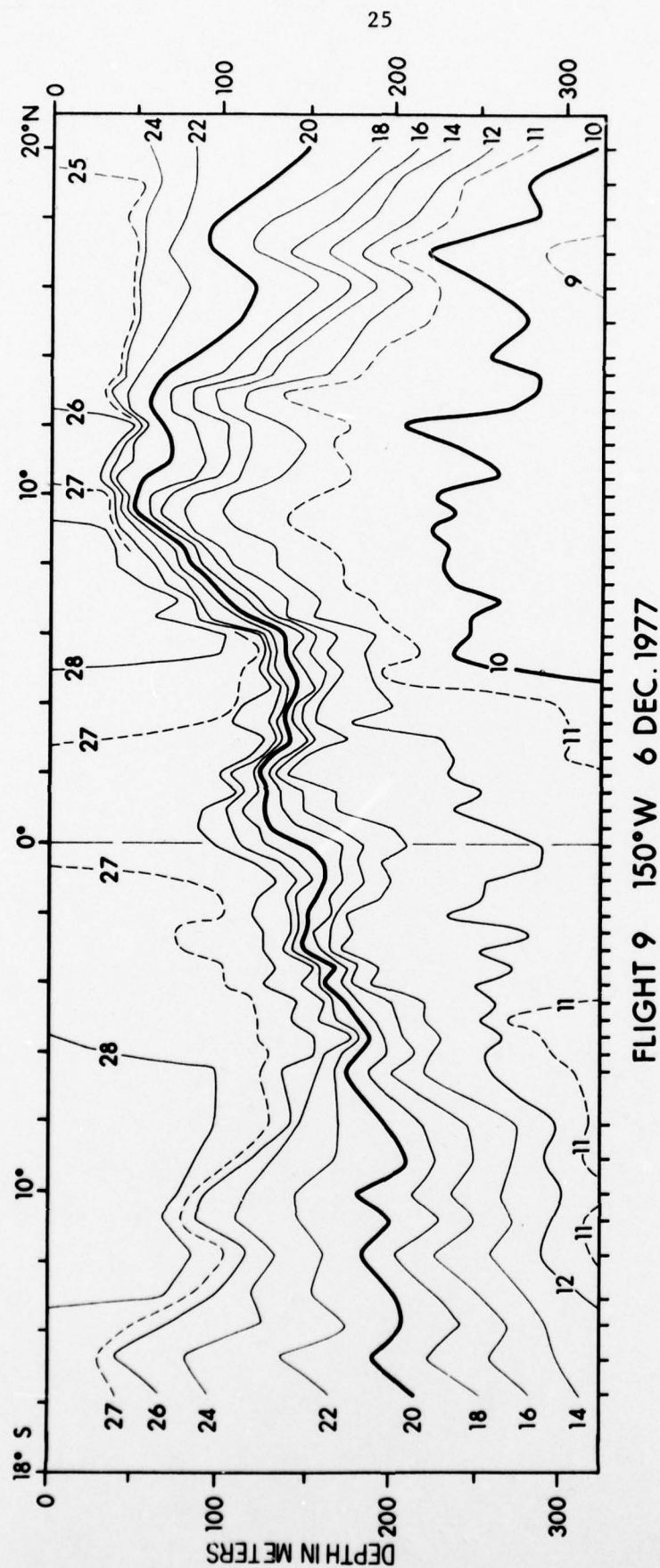
Section 6. Temperature in degrees centigrade along 150°W collected using AXBTs from a U.S. Navy Reserve P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



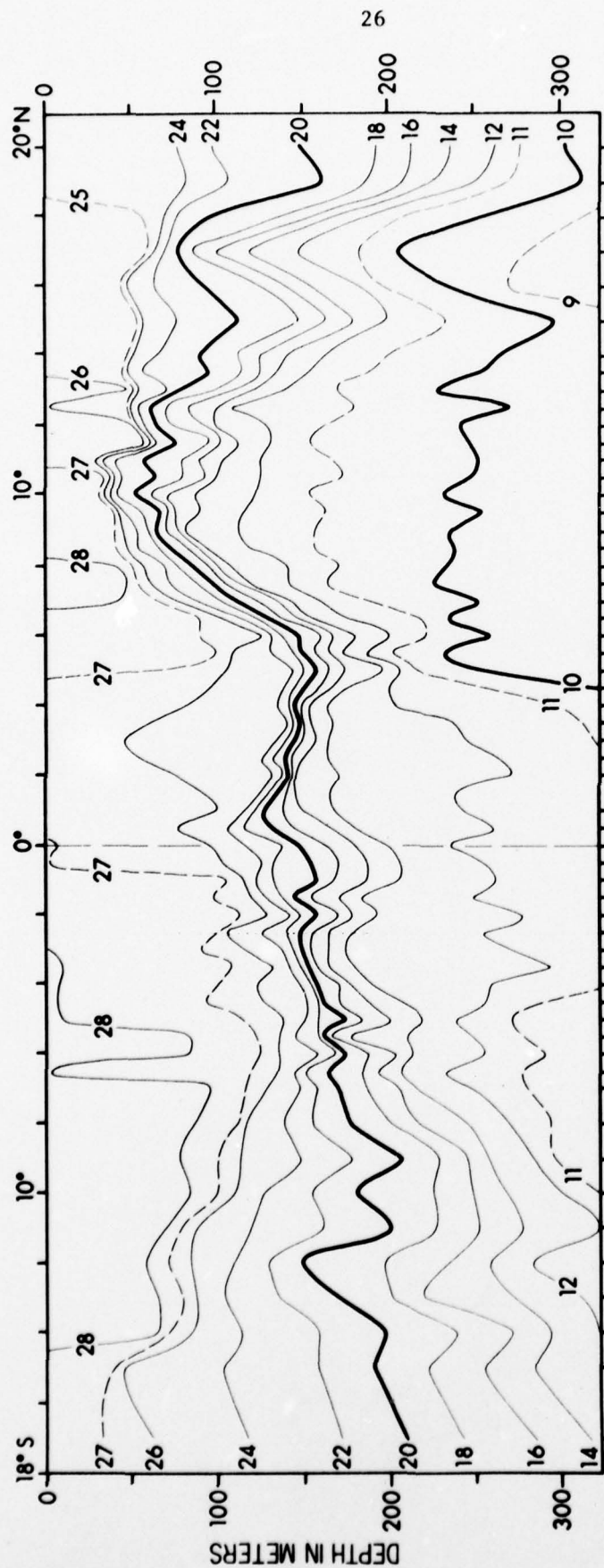


# FLIGHT 7 150°W 29 NOV. 1977

Section 7. Temperature in degrees centigrade along 150°W collected using AXBTs from a National Oceanic and Atmospheric Administration P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.

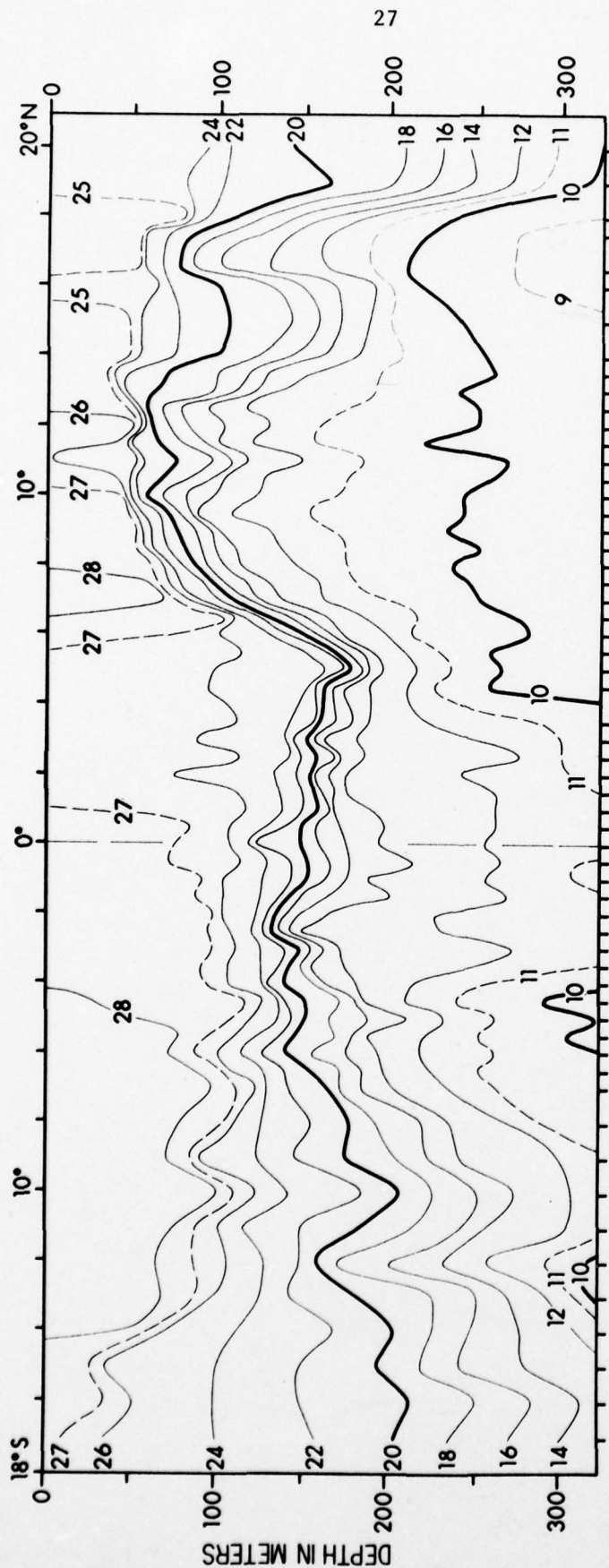


Section 8. Temperature in degrees centigrade along 150°W collected using AXBTs from a National Oceanic and Atmospheric Administration P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



# FLIGHT 11 150°W 13 DEC. 1977

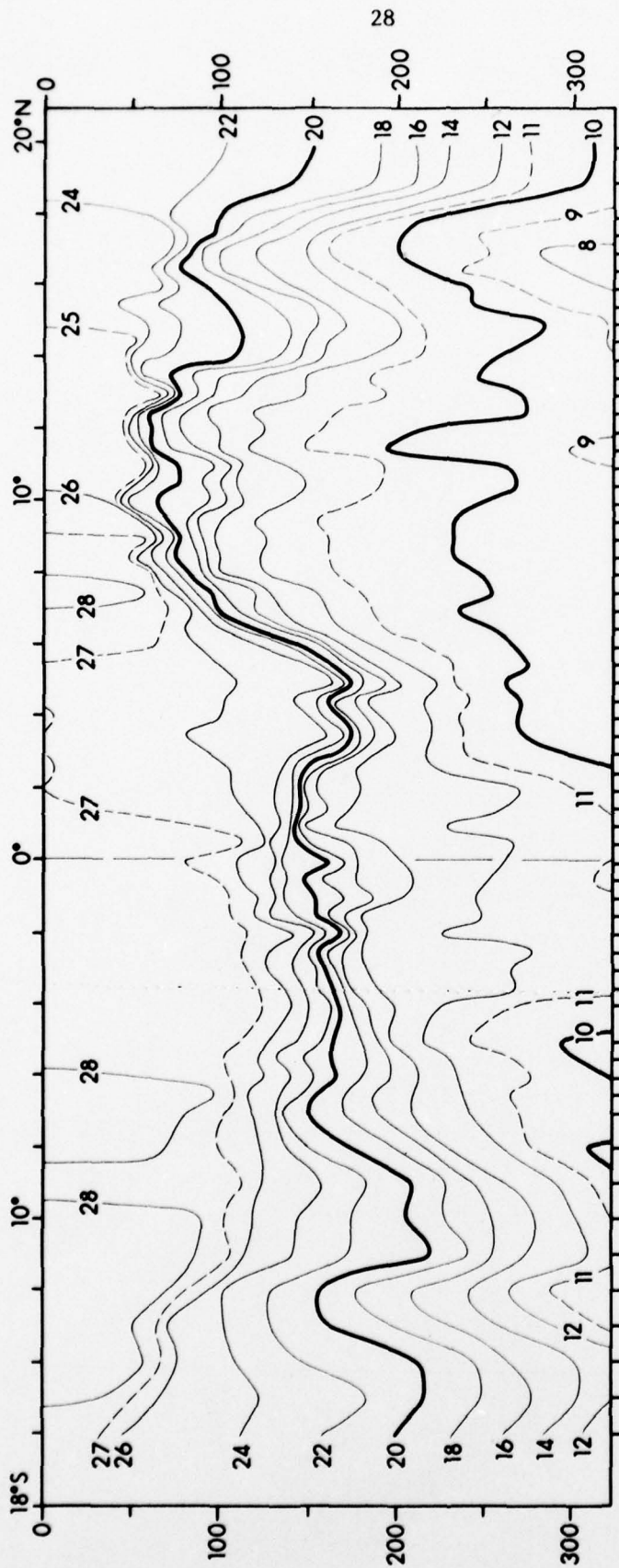
Section 9 . Temperature in degrees centigrade along 150°W collected using AXBTs from a National Oceanic and Atmospheric Administration P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



# FLIGHT 13 150°W 20 DEC. 1977

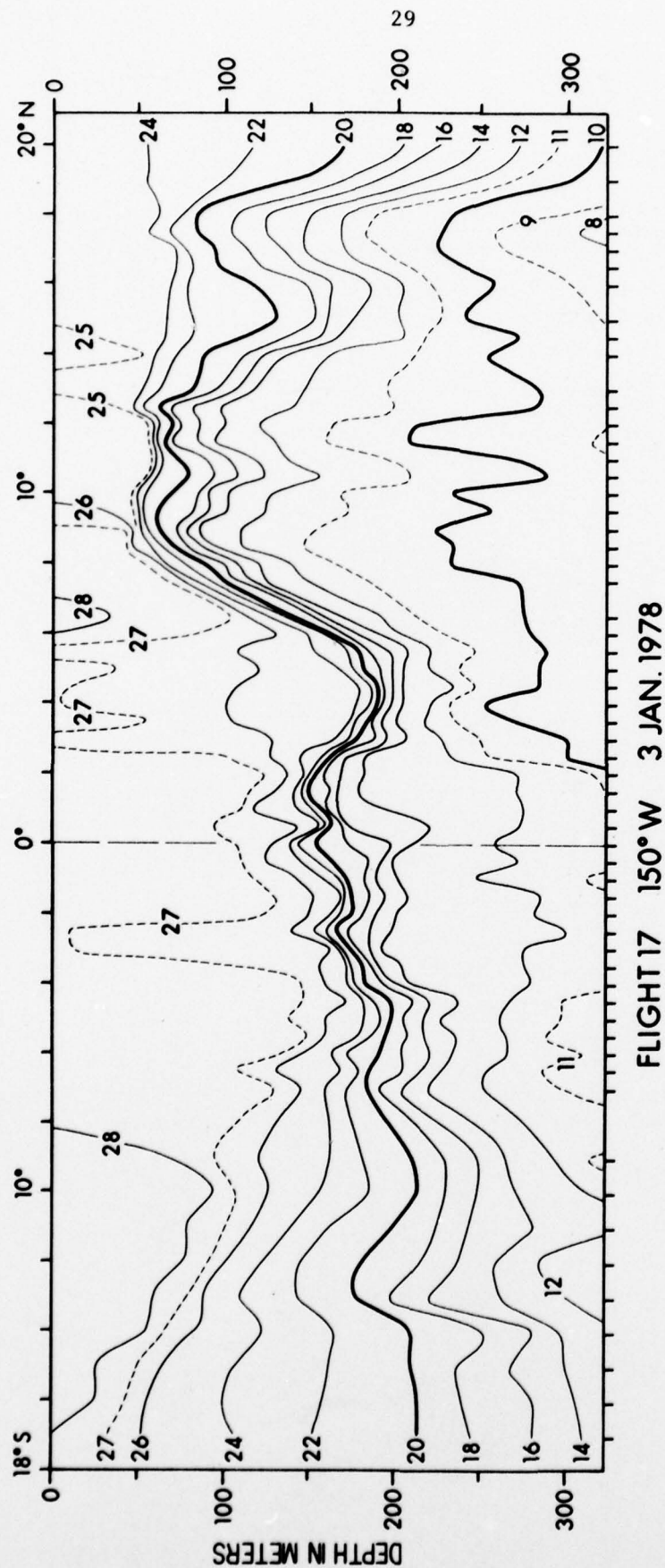
Section 10. Temperature in degrees centigrade along 150°W collected using AXBTs from a National Oceanic and Atmospheric Administration P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.





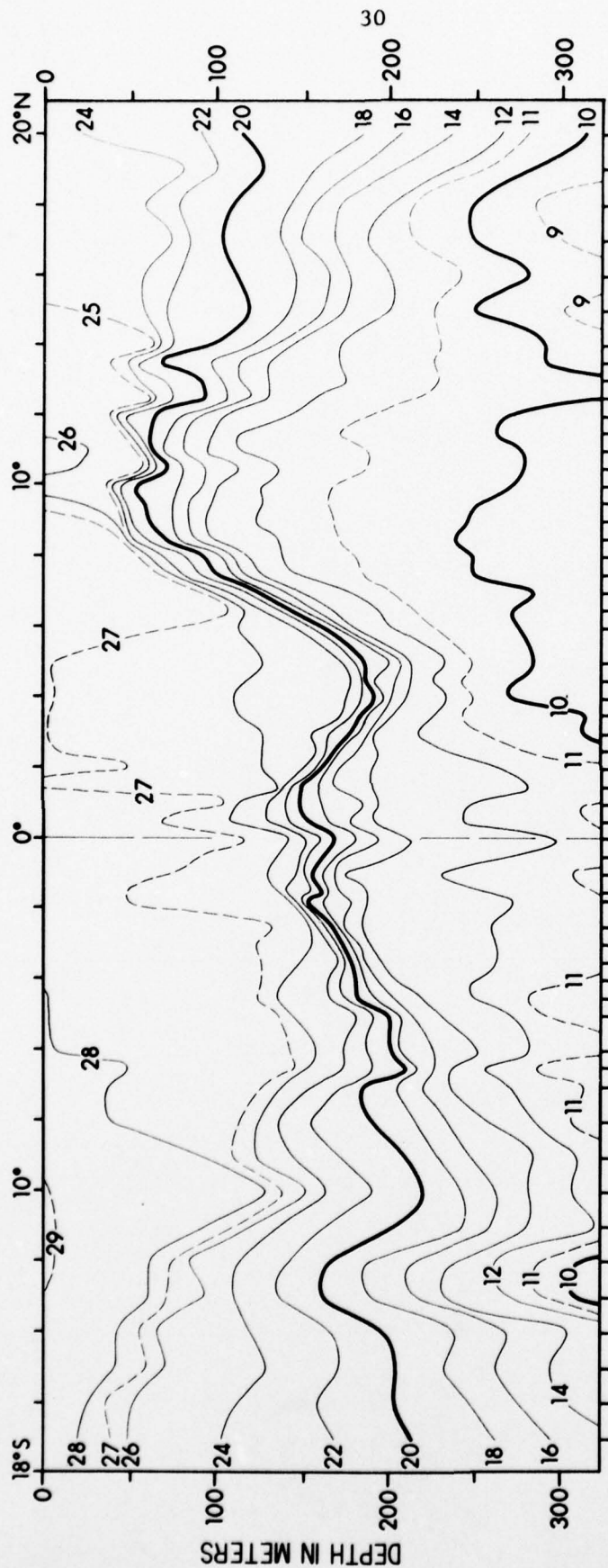
# FLIGHT 15 150°W 27 DEC. 1977

Section 11. Temperature in degrees centigrade along 150°W collected using AXBTs from a National Oceanic and Atmospheric Administration P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



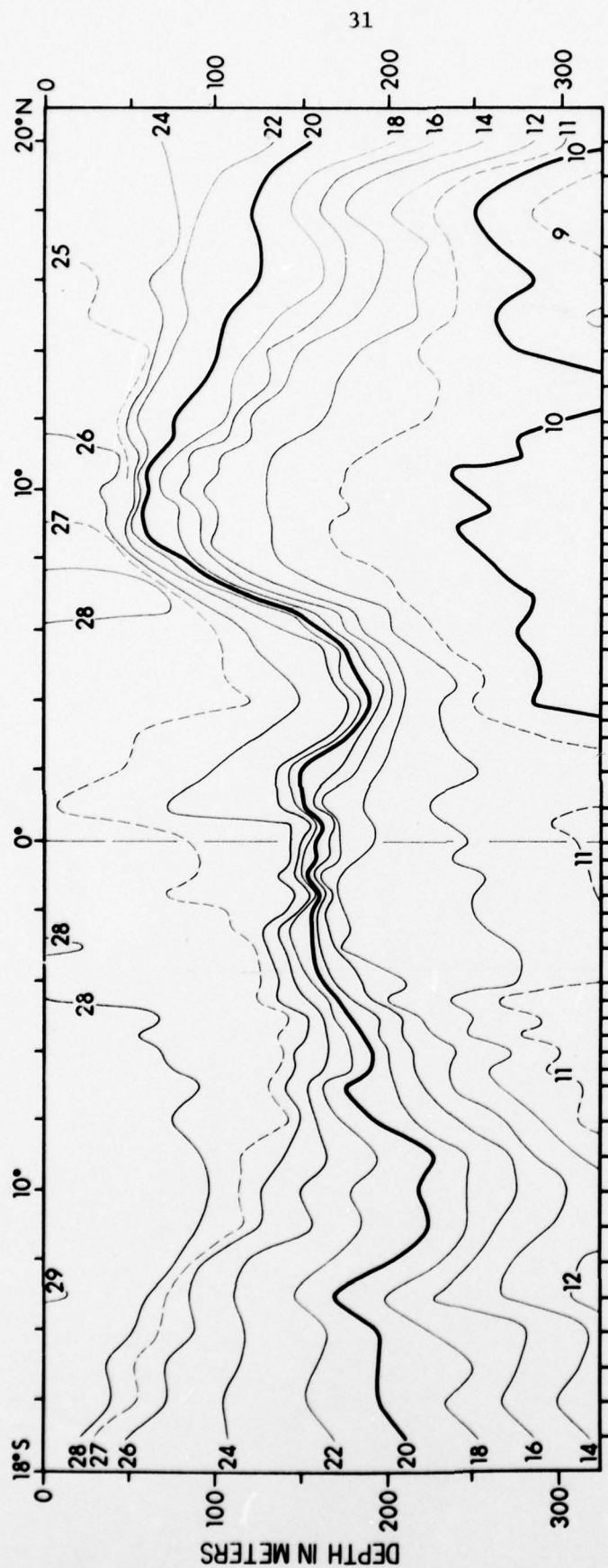
FLIGHT 17 150°W 3 JAN. 1978

Section 12. Temperature in degrees centigrade along 150°W collected using AXBTs from a National Oceanic and Atmospheric Administration P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



FLIGHT 19 150°W 10 JAN. 1978

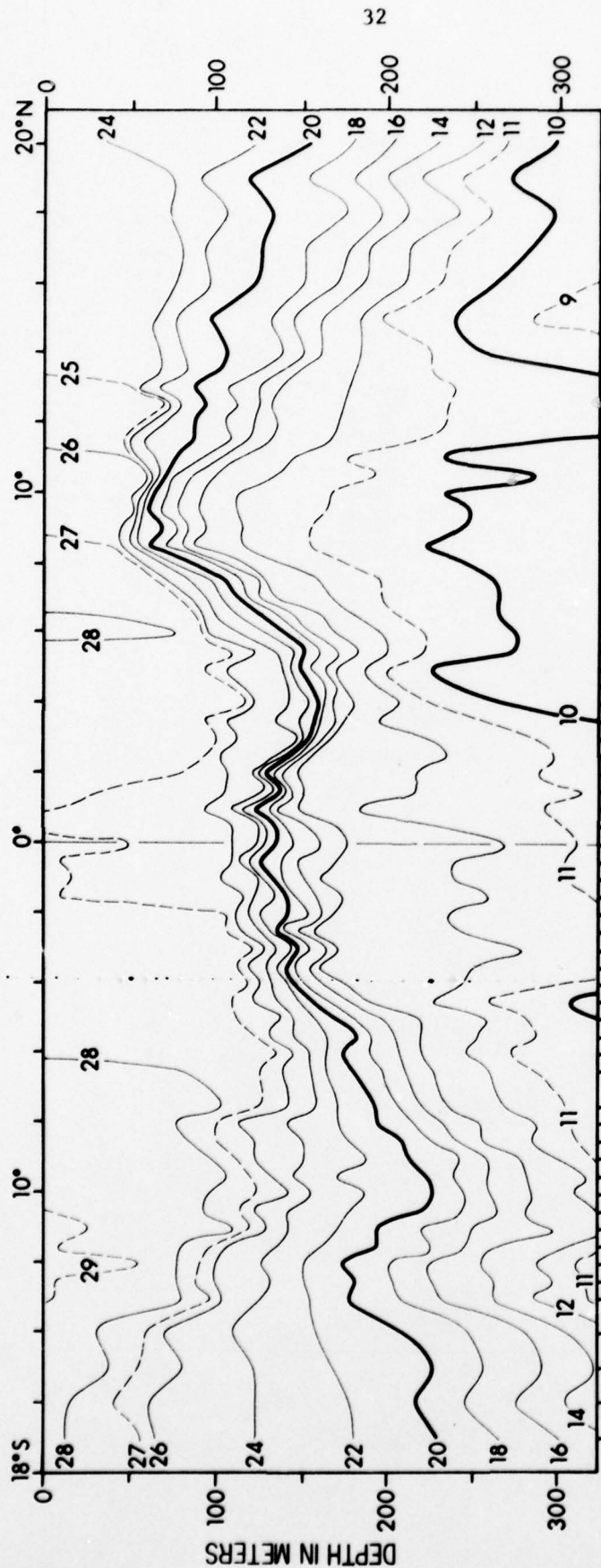
Section 13. Temperature in degrees centigrade along 150°W collected using AXBTs from a U.S. Navy Reserve P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



# FLIGHT 21 150°W 14 JAN. 1978

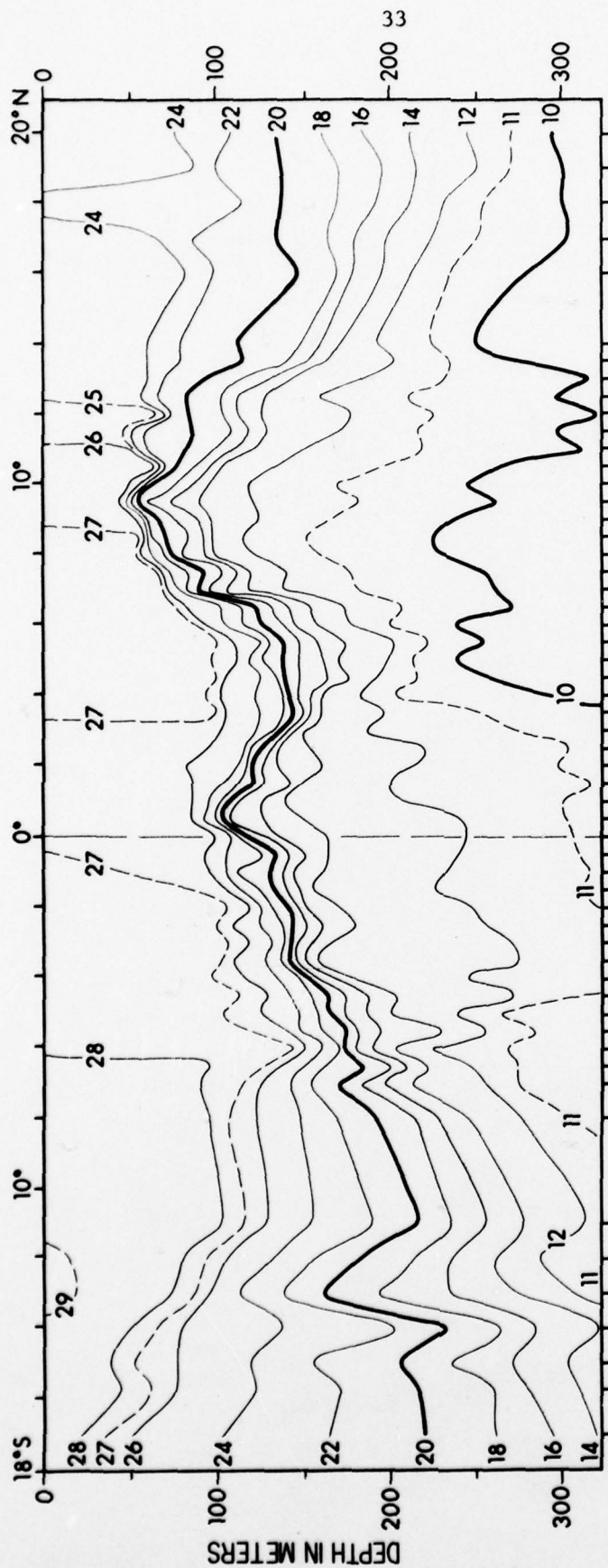
Section 14. Temperature in degrees centigrade along 150°W collected using AXBTs from a U.S. Navy Reserve P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.





### FLIGHT 23 150°W 24 JAN. 1978

Section 15. Temperature in degrees centigrade along 150°W collected using AXBTs from a U.S. Navy reserve P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



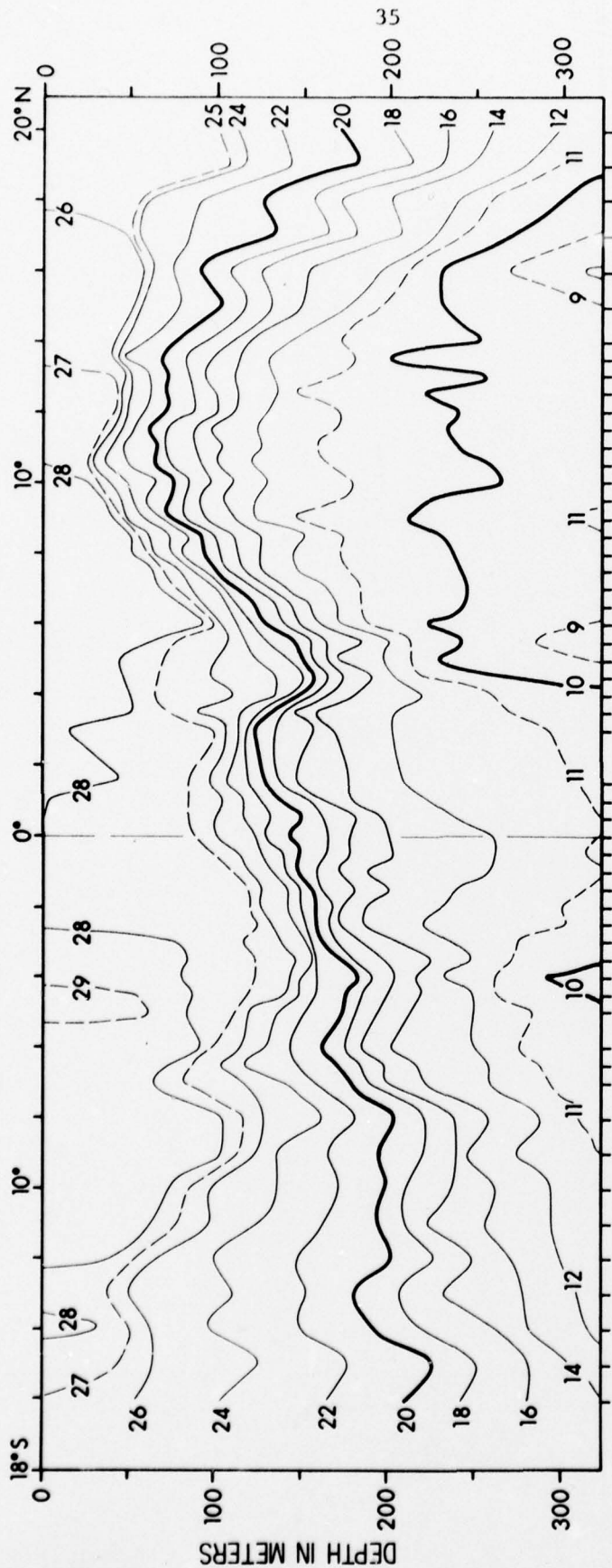
# FLIGHT 25 150°W 30 JAN. 1978

Section 16. Temperature in degrees centigrade along 150°W collected using AXBTs from a U.S. Naval Oceanographic Office P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of the AXBT drops are indicated by dashes at the bottom of the figure.

SECTIONS 17-26

158°W

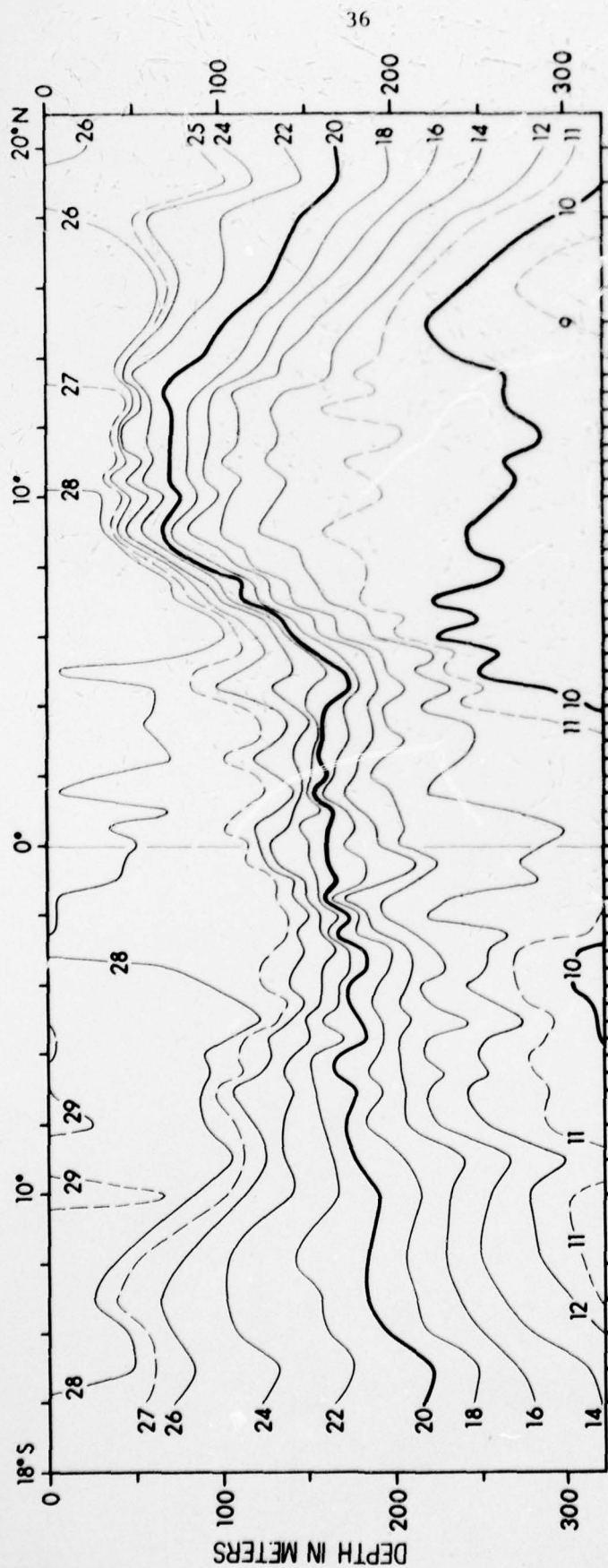




### FLIGHT 8 158°W 2 DEC. 1977

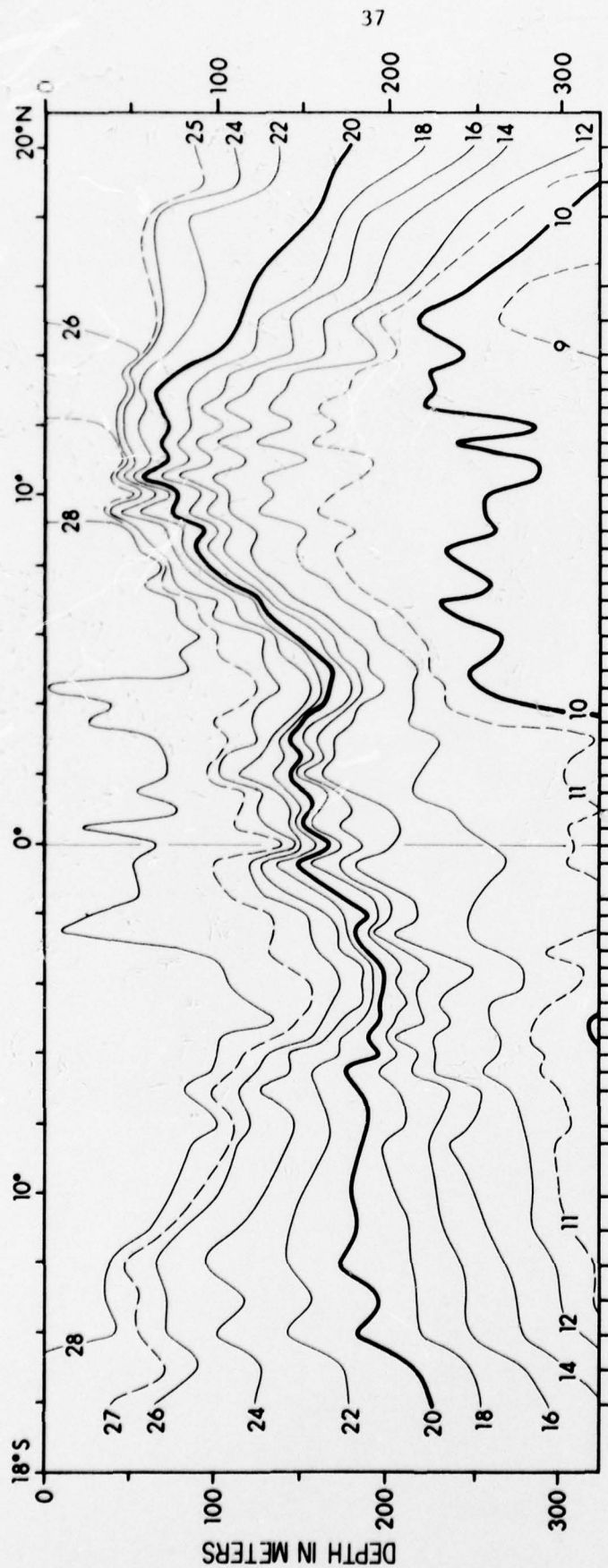
Section 17. Temperature in degrees centigrade along 158°W collected using AXBTs from a National Oceanic and Atmospheric Administration P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of the AXBT drops are indicated by dashes at the bottom of the figure.



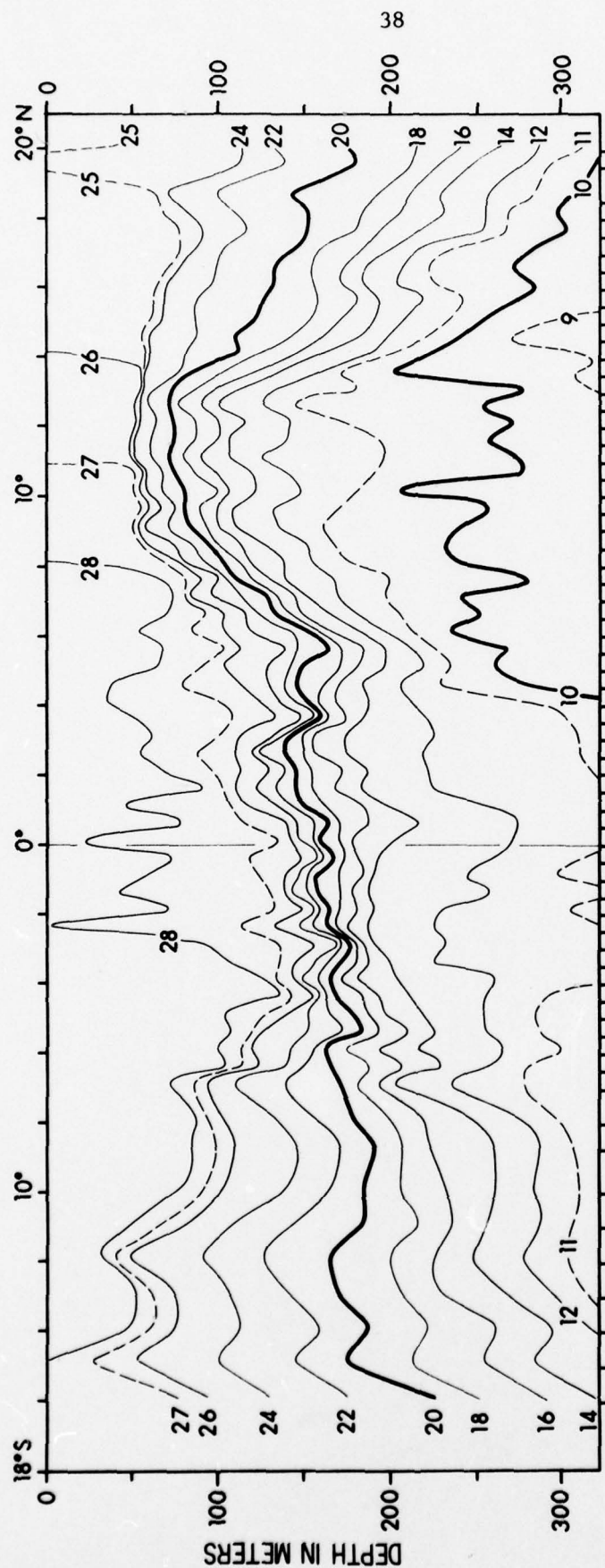


### FLIGHT 10 158°W 9 DEC. 1977

Section 18. Temperature in degrees centigrade along 158°W collected using AXBTs from a National Oceanic and Atmospheric Administration P-3 aircraft during the NORPAX Pre-FGSE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.

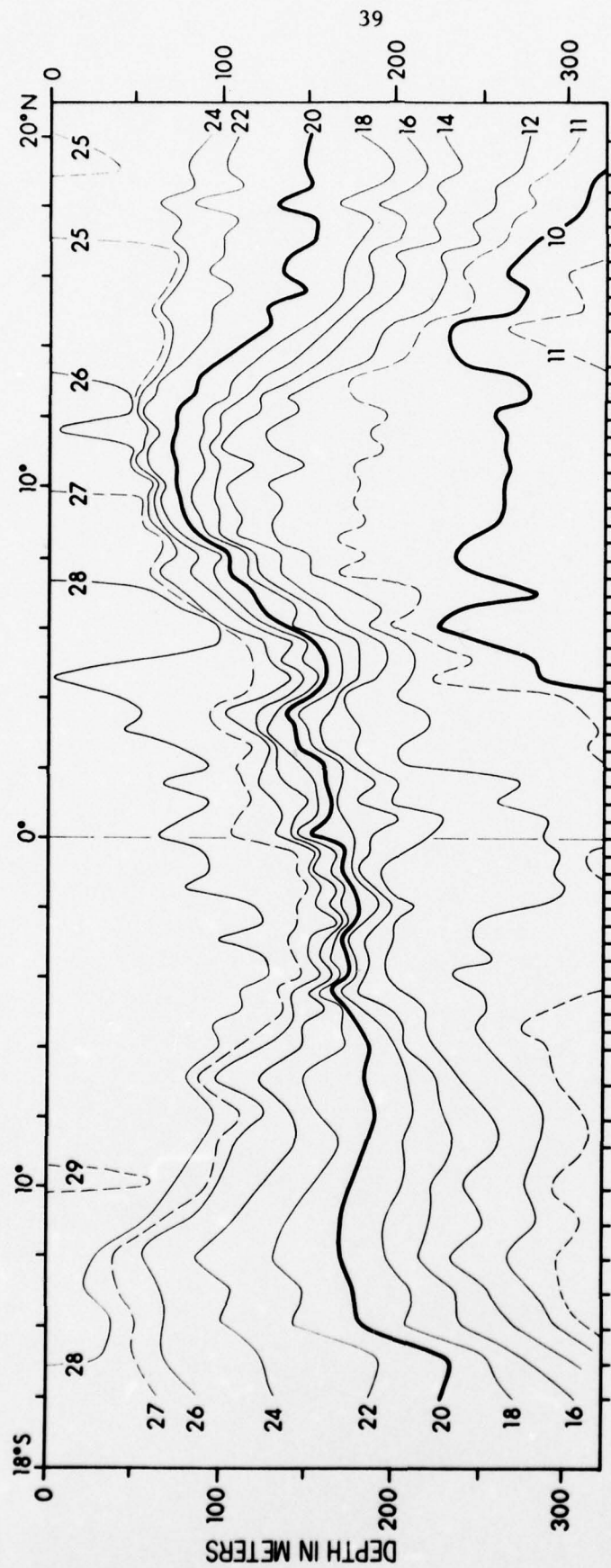


Section 19. Temperature in degrees centigrade along 158°W collected using AXBTs from a National Oceanic and Atmospheric Administration P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



# FLIGHT 14 158°W 22 DEC. 1977

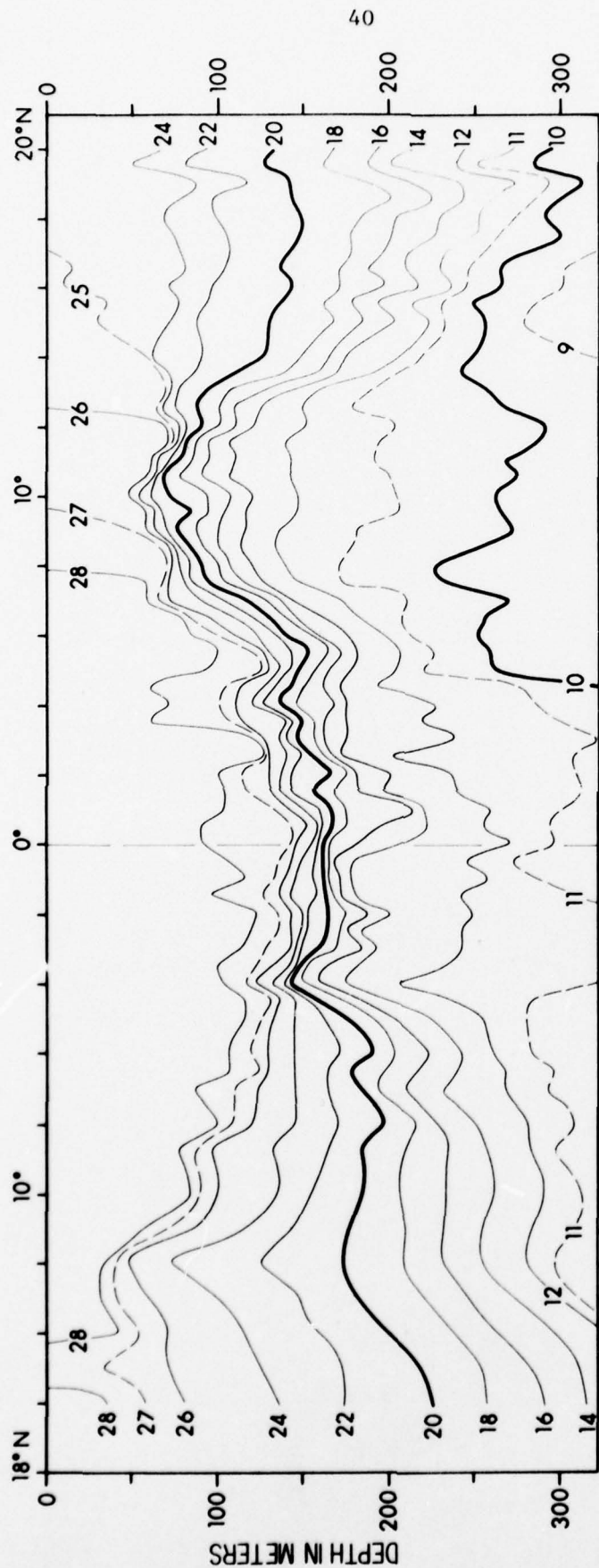
Section 20. Temperature in degrees centigrade along 158°W collected using AXBTs from a National Oceanic and Atmospheric Administration P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



# FLIGHT 16 158°W 29 DEC. 1977

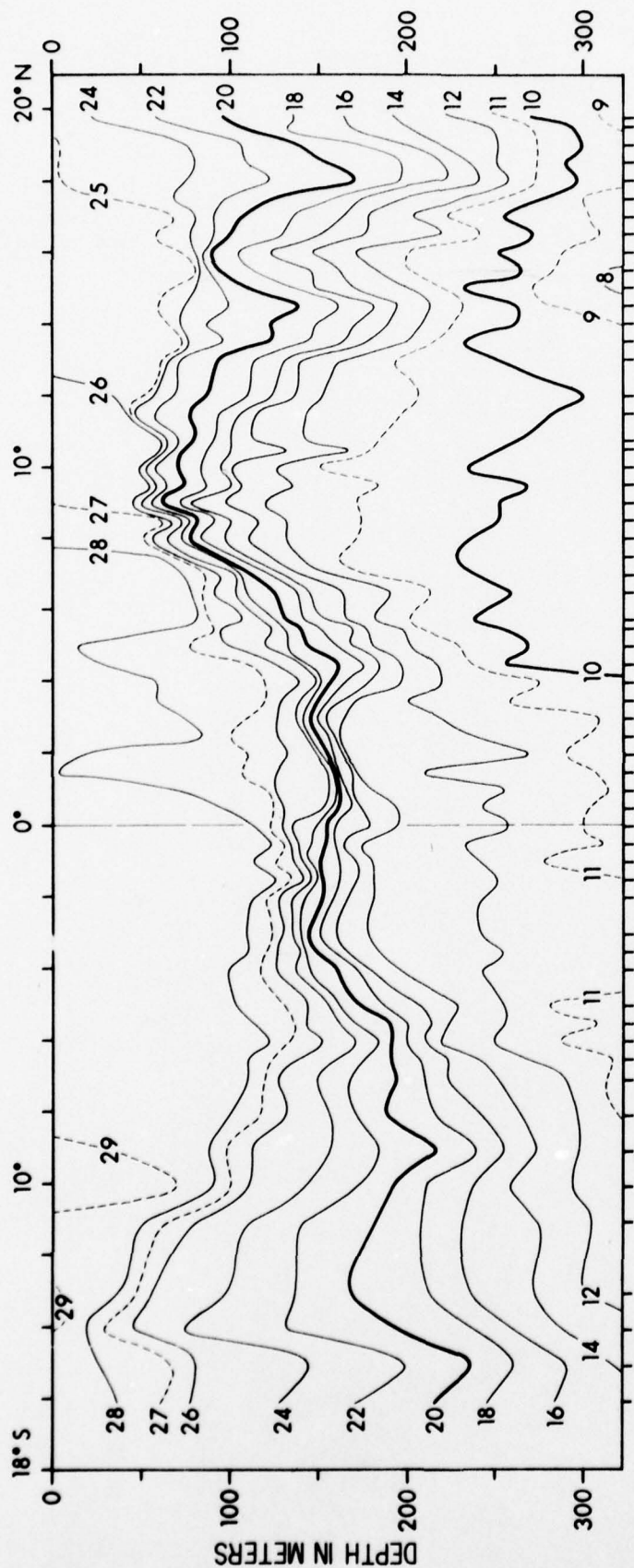
Section 21. Temperature in degrees centigrade along 158°W collected using AXBTs from a National Oceanic and Atmospheric Administration P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.





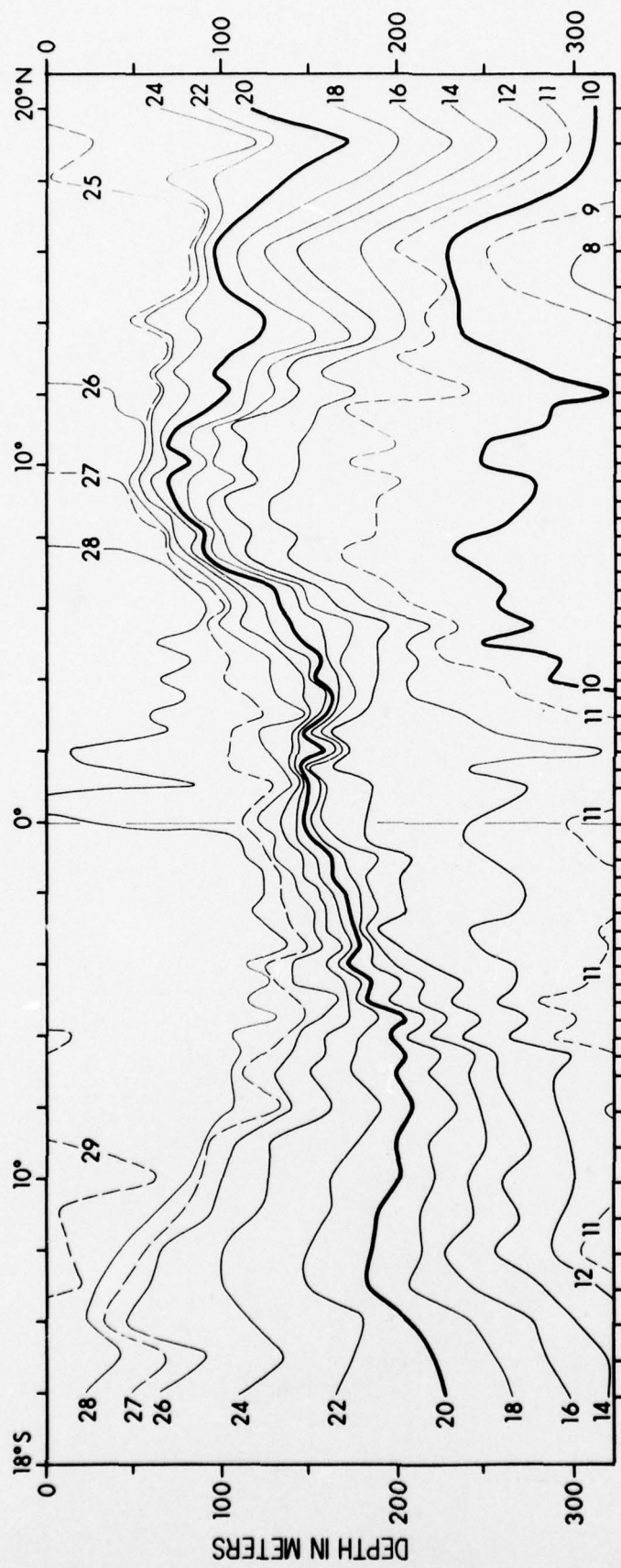
FLIGHT 18 158°W 5 JAN. 1978

Section 22. Temperature in degrees centigrade along 158°W collected using AXBTs from a National Oceanic and Atmospheric Administration P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



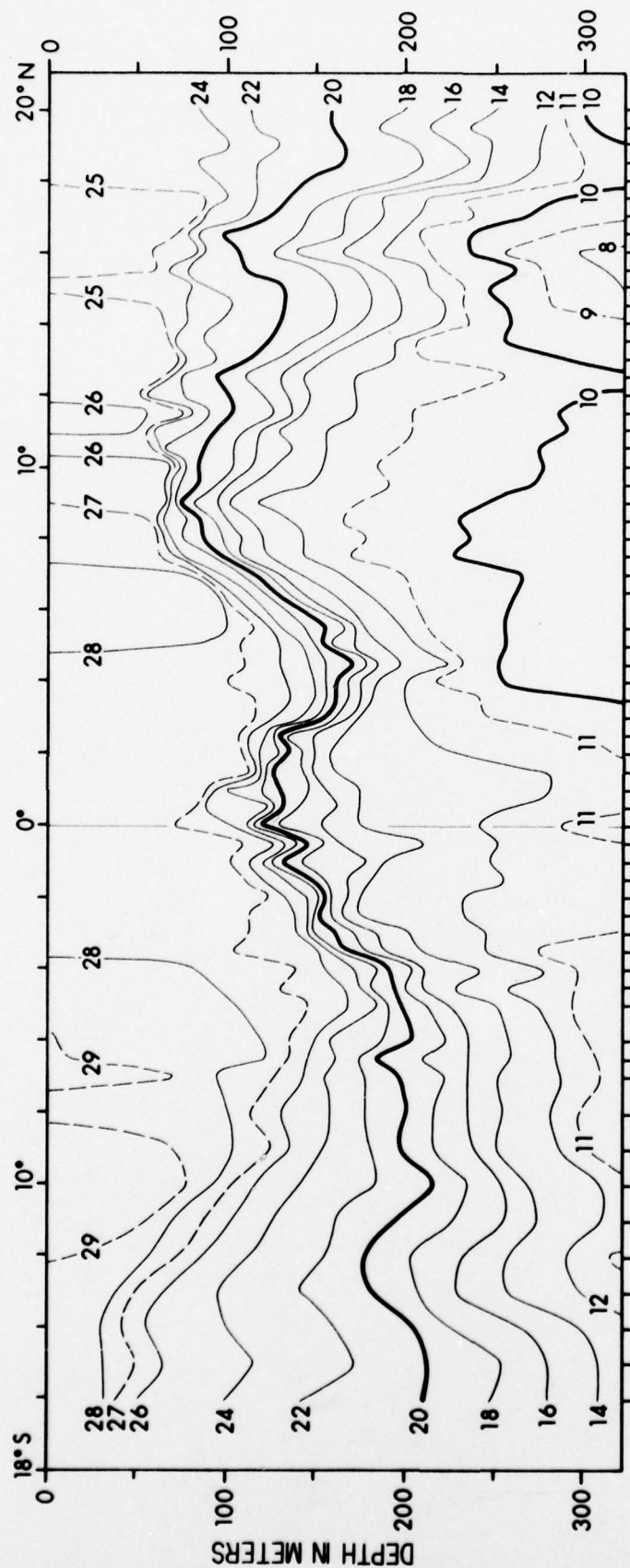
FLIGHT 20 158°W 12 JAN, 1978

Section 23. Temperature in degrees centigrade along 158°W collected using AXBTs from a U.S. Navy Reserve P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



FLIGHT 22 158°W 16 JAN. 1978

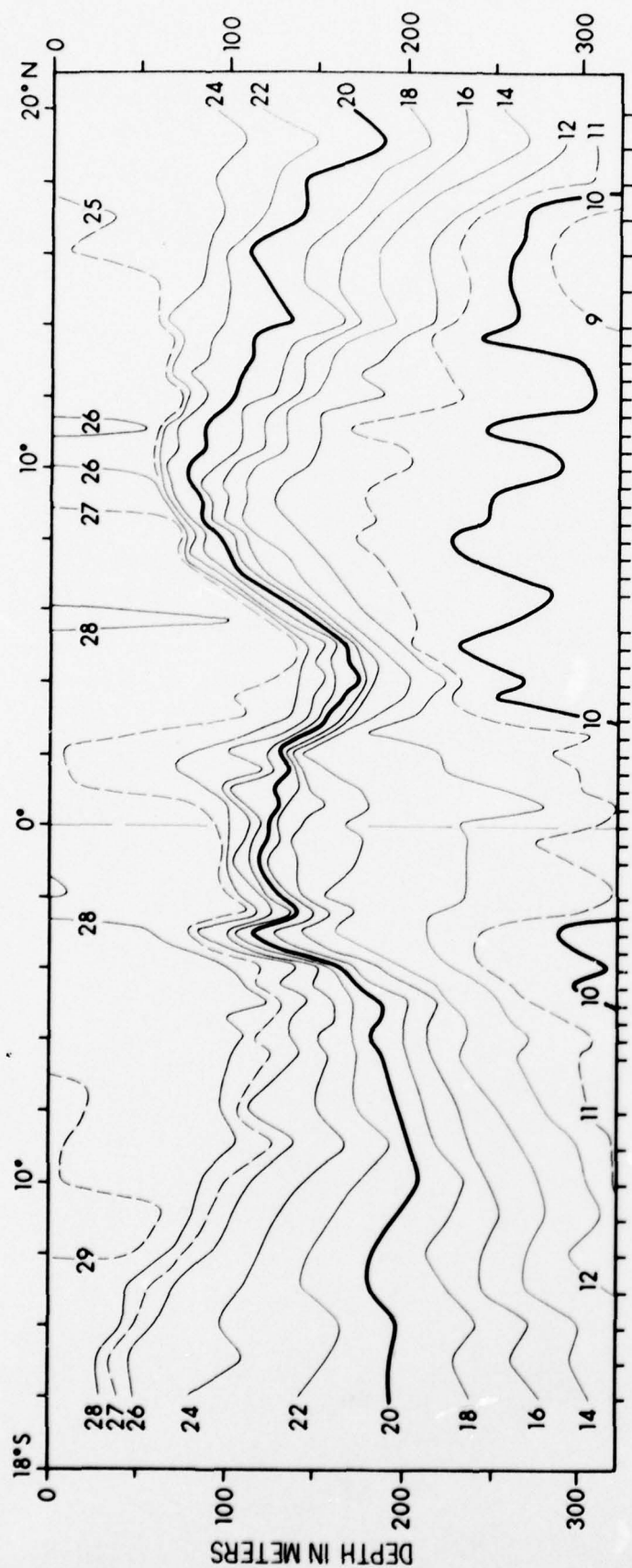
Section 24. Temperature in degrees centigrade along 158°W collected using AXBTs from a U.S. Navy Reserve P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



# FLIGHT 24 158°W 26 JAN. 1978

Section 25. Temperature in degrees centigrade along 158°W collected using AXBTs from a U.S. Navy Reserve P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.





FLIGHT 26 158°W 1 FEB. 1978

Section 26. Temperature in degrees centigrade along 158°W collected using AXBTs from a U.S. Naval Oceanographic Office P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. Locations of AXBT drops are indicated by dashes at the bottom of the figure.

FIGURES 2-17

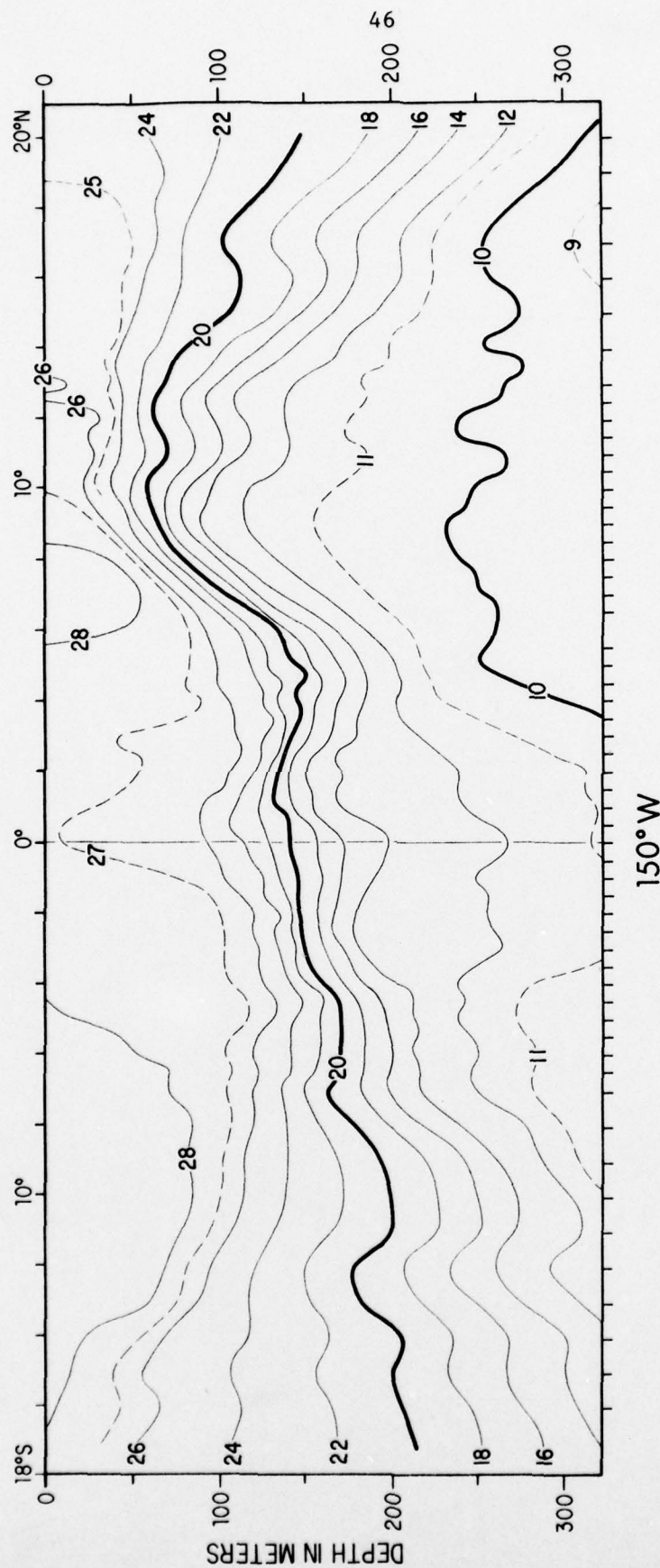


Figure 2. Mean temperature in degrees centigrade along 150°W calculated from AXBTs collected from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 5 November, 1977 to 30 January, 1978 (Sections 1-16). Locations of AXBT drops are indicated by dashes at the bottom of the figure.



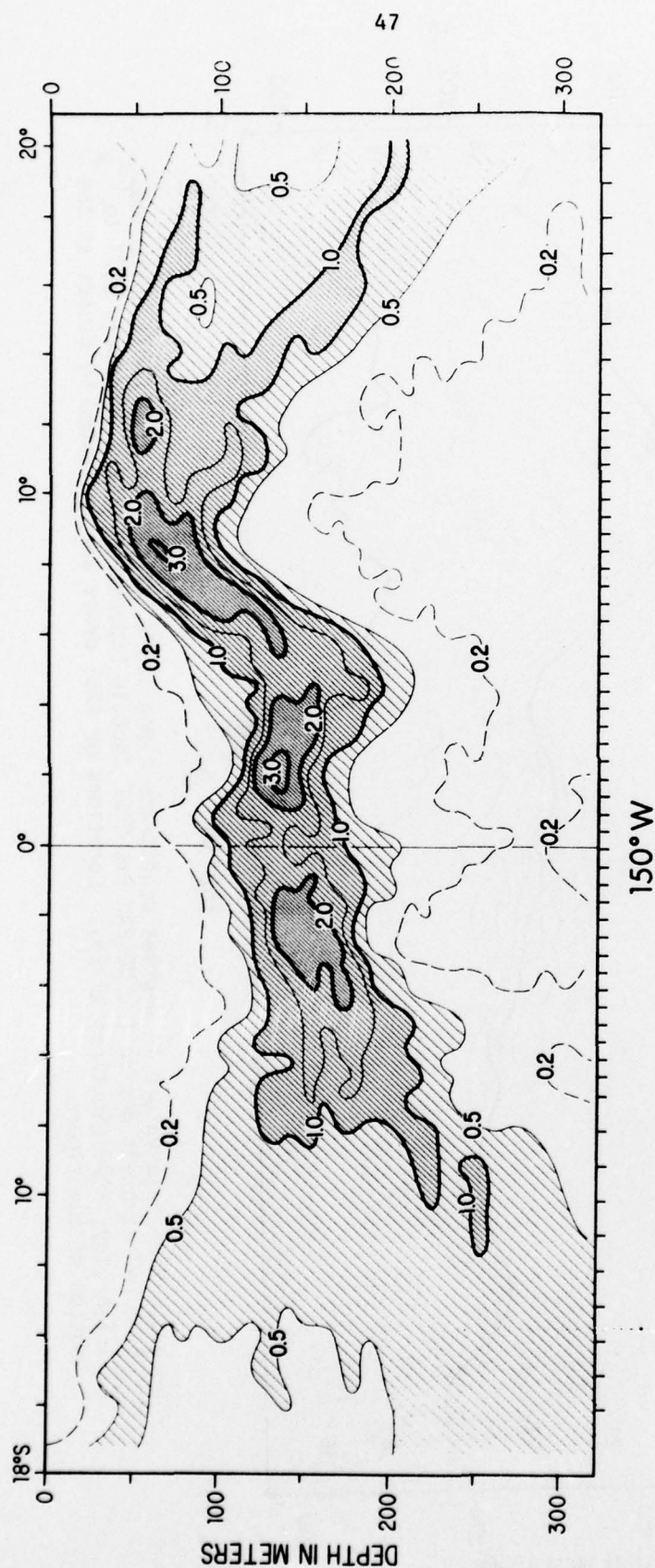


Figure 3. Mean temperature gradient ( $\partial T/\partial z$ ) in degrees centigrade per 10 meters of depth along  $150^\circ\text{W}$ , collected from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 5 November, 1977 to 30 January, 1978 (Sections 1-16). Locations of AXBT drops are indicated by dashes at the bottom of the figure.



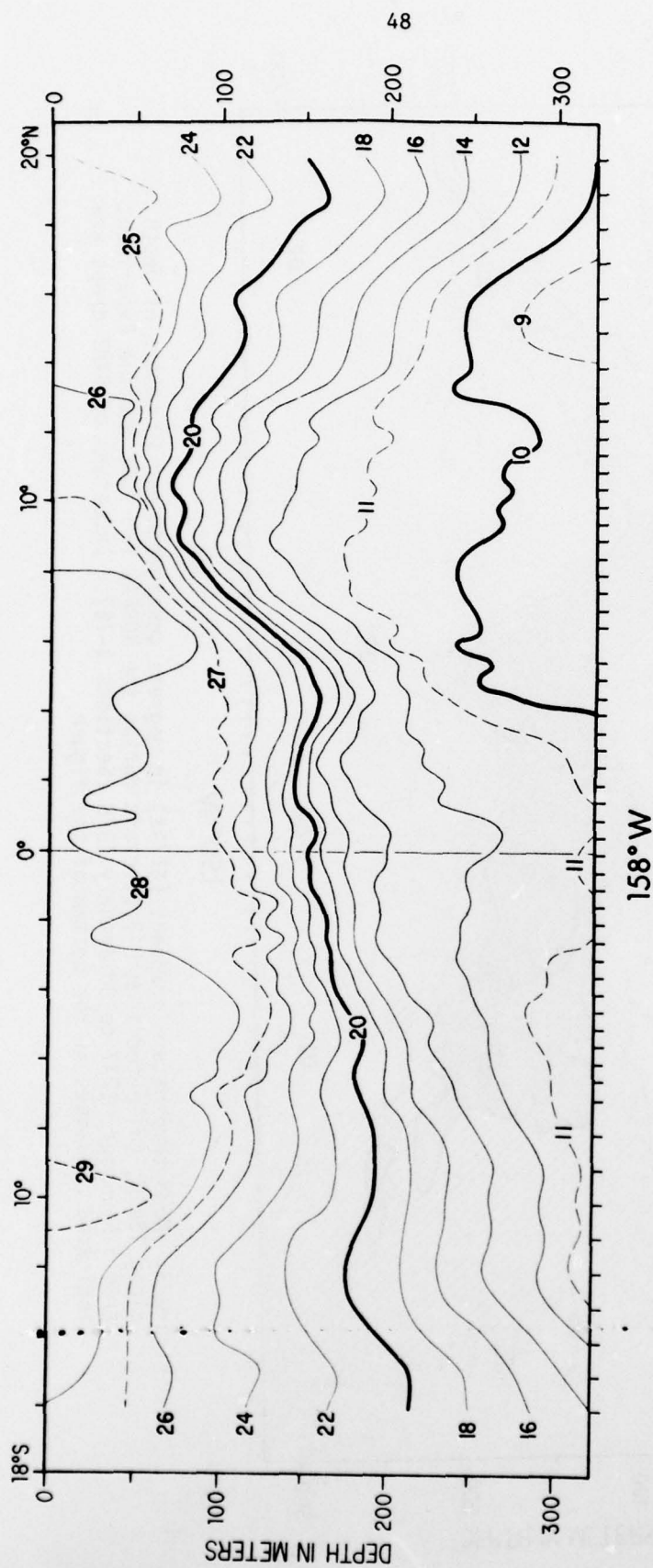


Figure 4. Mean temperature in degrees centigrade along 158°W, calculated from AXBTs collected from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 2 December, 1977 to 1 February, 1978 (Sections 17-26). Locations of AXBT drops are indicated by dashes at the bottom of the figure.

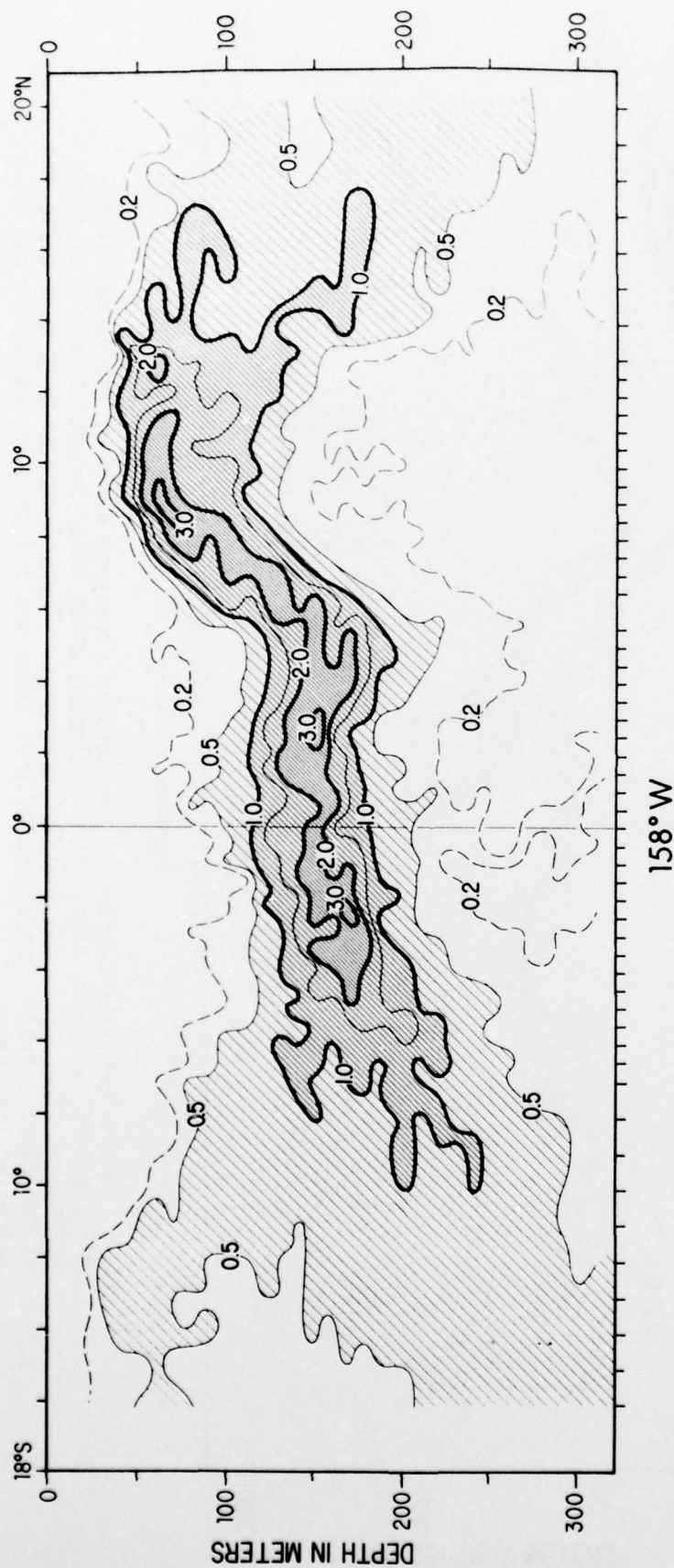


Figure 5. Mean temperature gradient ( $\partial T / \partial z$ ) in degrees centigrade per 10 meters of depth along 158°W, calculated from AXBTs collected from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 2 December, 1977 to 1 February, 1978 (Sections 17-26). Locations of AXBT drops are indicated by dashes at the bottom of the figure.

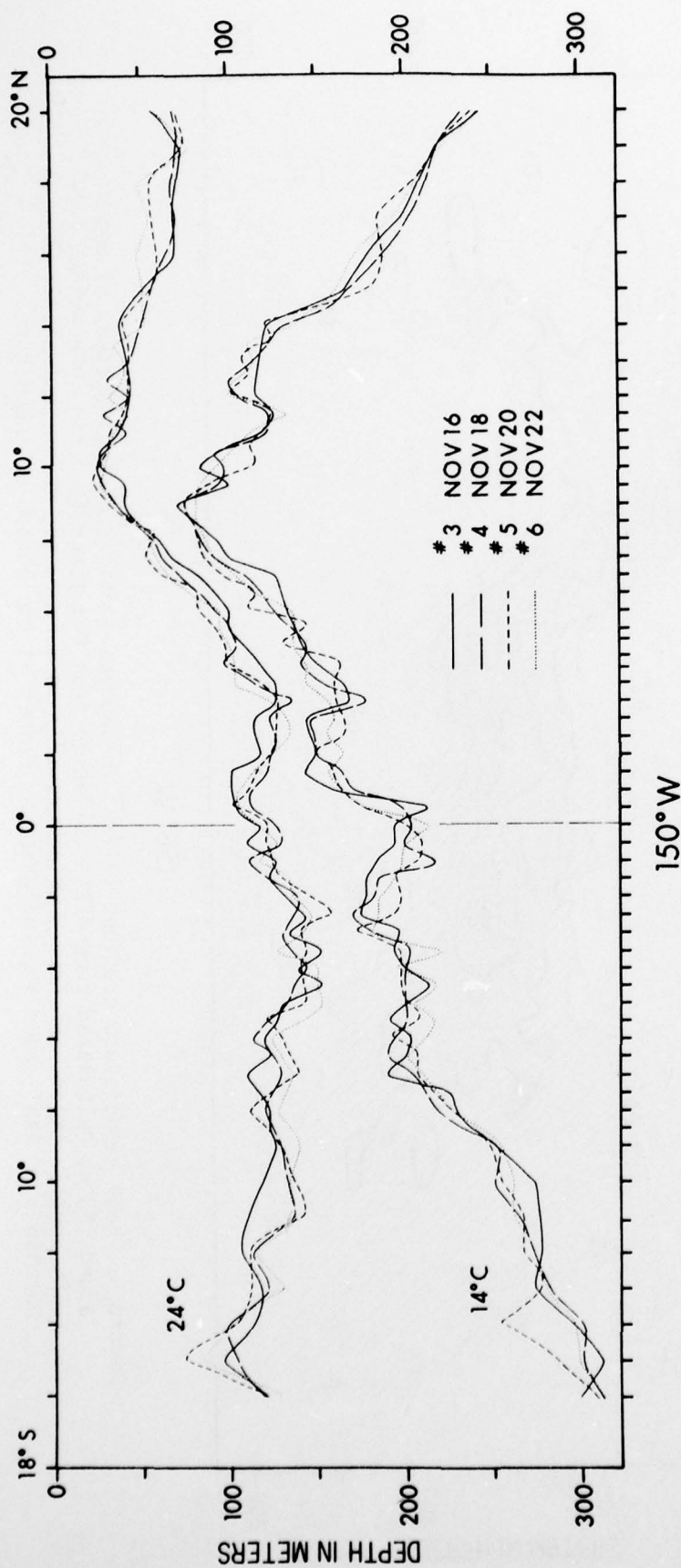


Figure 6. Short-term fluctuations of the thermal structure shown by the depths of the 24°C and 14°C isotherms along 150°W collected using AXBTs dropped from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment. These four data sets were collected at two day intervals. Locations of AXBT drops are indicated by dashes at the bottom of the figure.

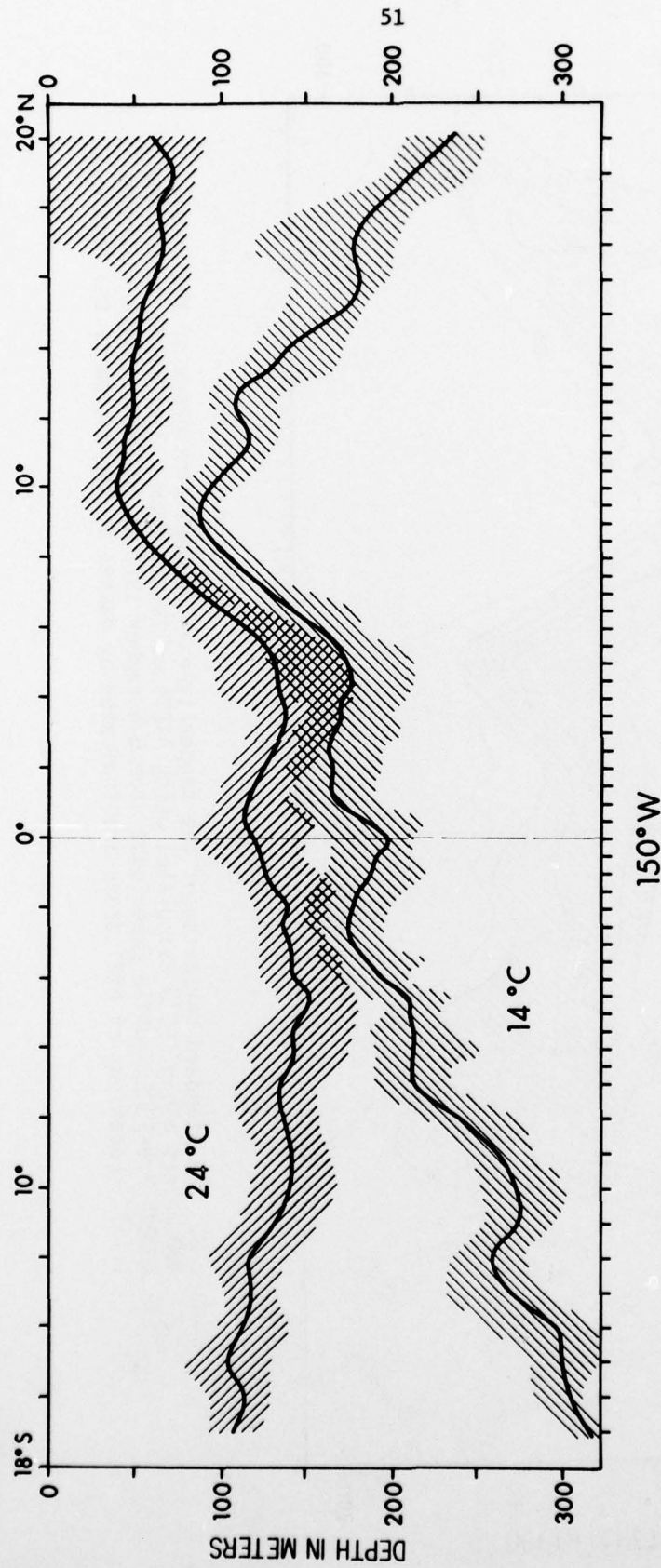


Figure 7. The total variability of the depth of the 24°C and 14°C isotherms (stippled areas) along 150°W calculated using the 16 AXBT sections collected from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 5 November, 1977 to 30 January, 1978. The mean depths of the 24°C and 14°C isotherms are given by the solid lines. Locations of AXBT drops are indicated by dashes at the bottom of the figure.



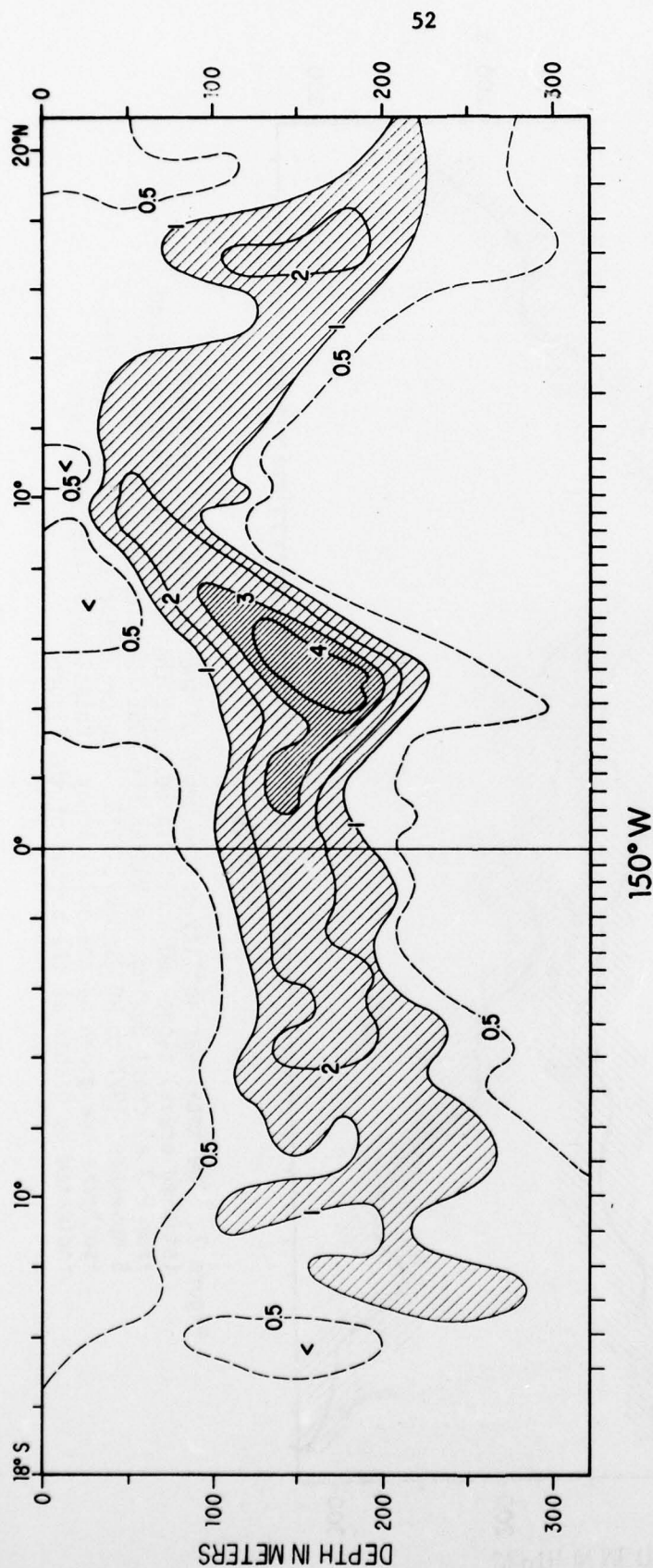


Figure 8. The standard deviation of the temperature in degrees centigrade of the upper 300 meters along 150°W calculated using AXBTs collected from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 5 November 1977 to 30 January 1978 (Sections 1-16). Locations of AXBT drops are indicated by dashes at the bottom of the figure.

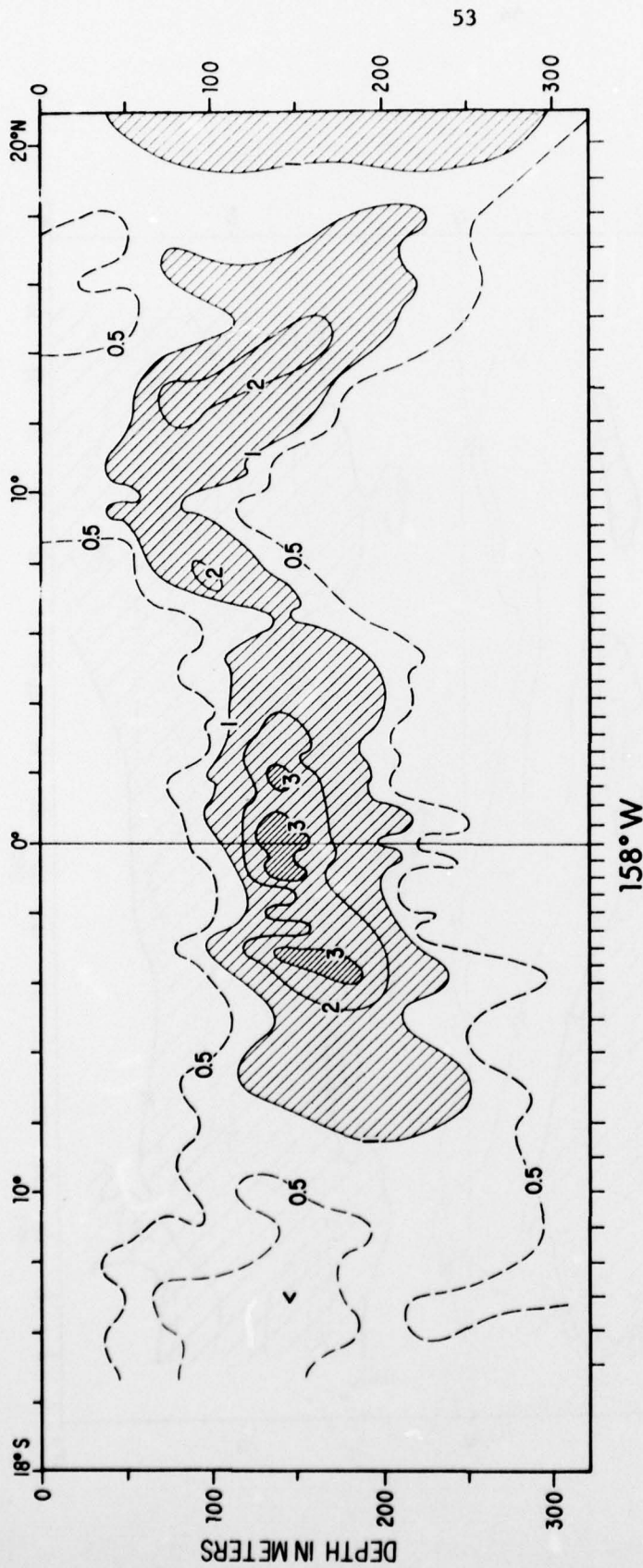


Figure 9. The standard deviation of the temperature in degrees centigrade of the upper 300 meters along 158°W calculated using AXBTs collected from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 2 December 1977 to 1 February 1978 (Sections 17-26). Locations of AXBT drops are indicated by dashes at the bottom of the figure.

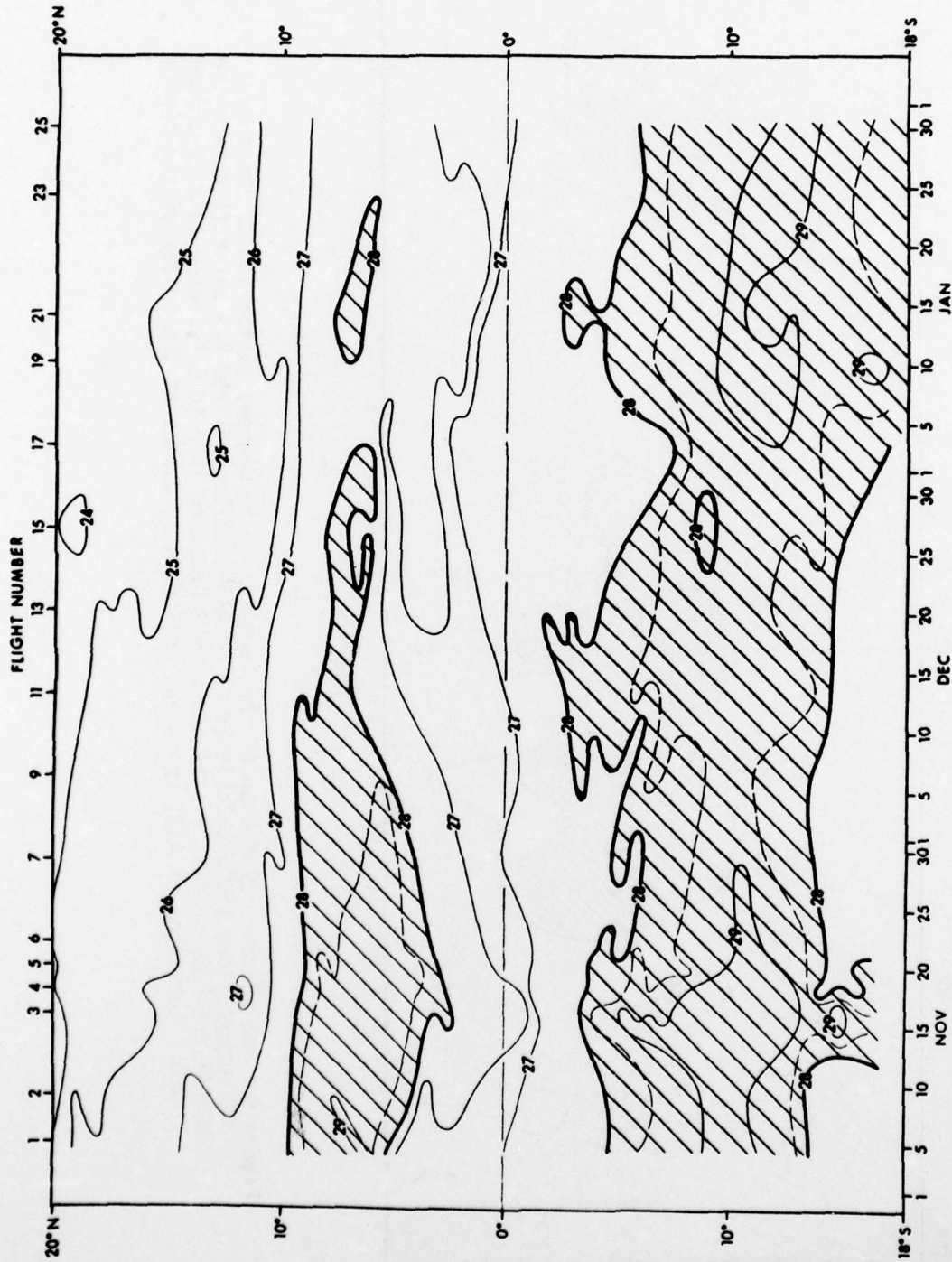


Figure 10. Sea surface temperature in degrees centigrade along 150°W collected using AXBTs from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 5 November, 1977 to 30 January, 1978 (Section 1-16).



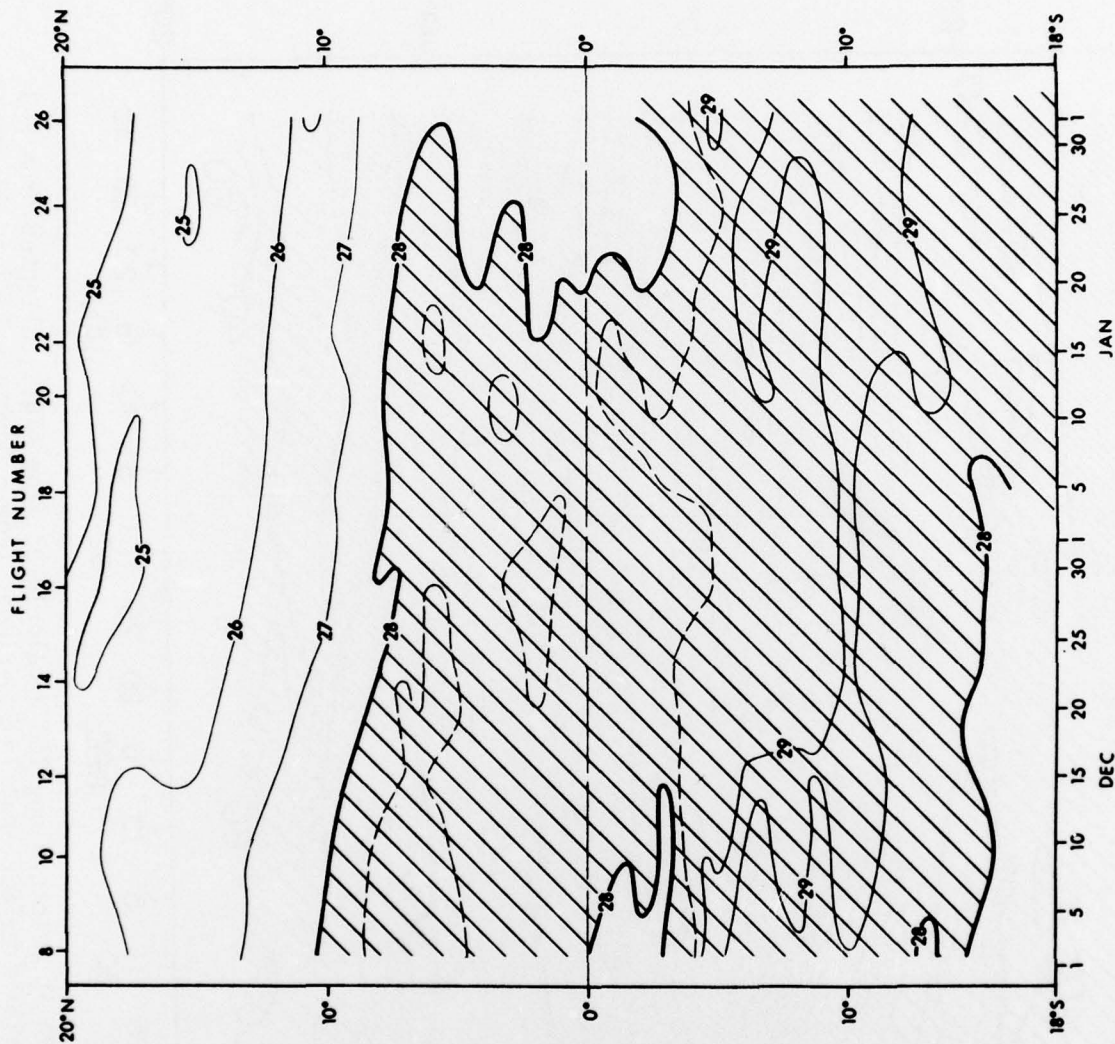


Figure 11. Sea surface temperature in degrees centigrade along 158°W calculated from AXBTs collected from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 2 December 1977 to 1 February 1978 (Sections 17-26).



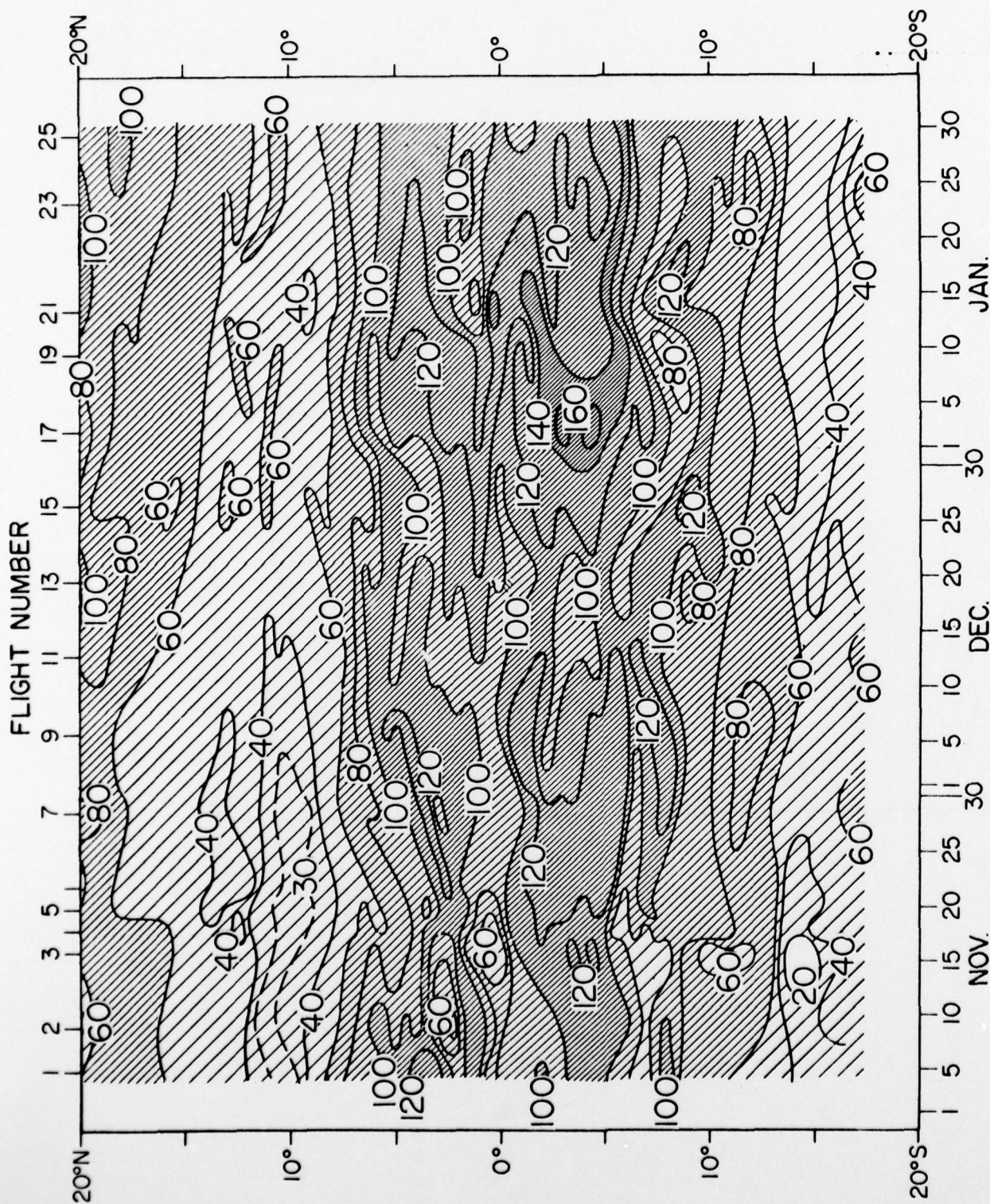


Figure 12. Mixed layer depth in meters along 150°W calculated from AXBTs collected from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 5 November 1977 to 30 January 1978 (Section 1-16). These contours represent a decrease of 1°C from the surface temperature.

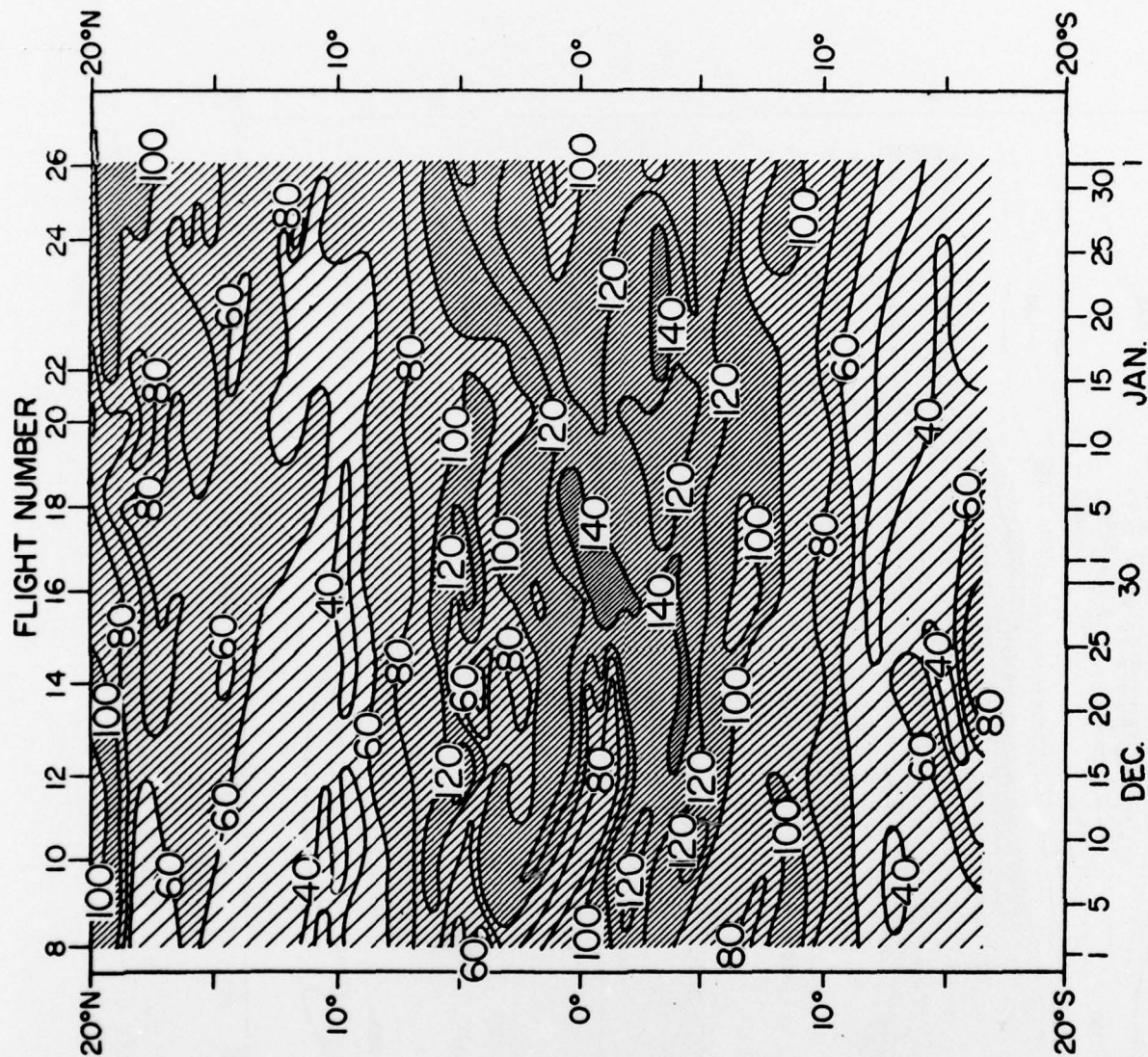


Figure 13. Mixed layer depth in meters along 158°W calculated from AXBTs collected from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 2 December 1977 to 1 February 1978 (Sections 17-26). These contours represent a decrease of 1°C from the surface temperature.



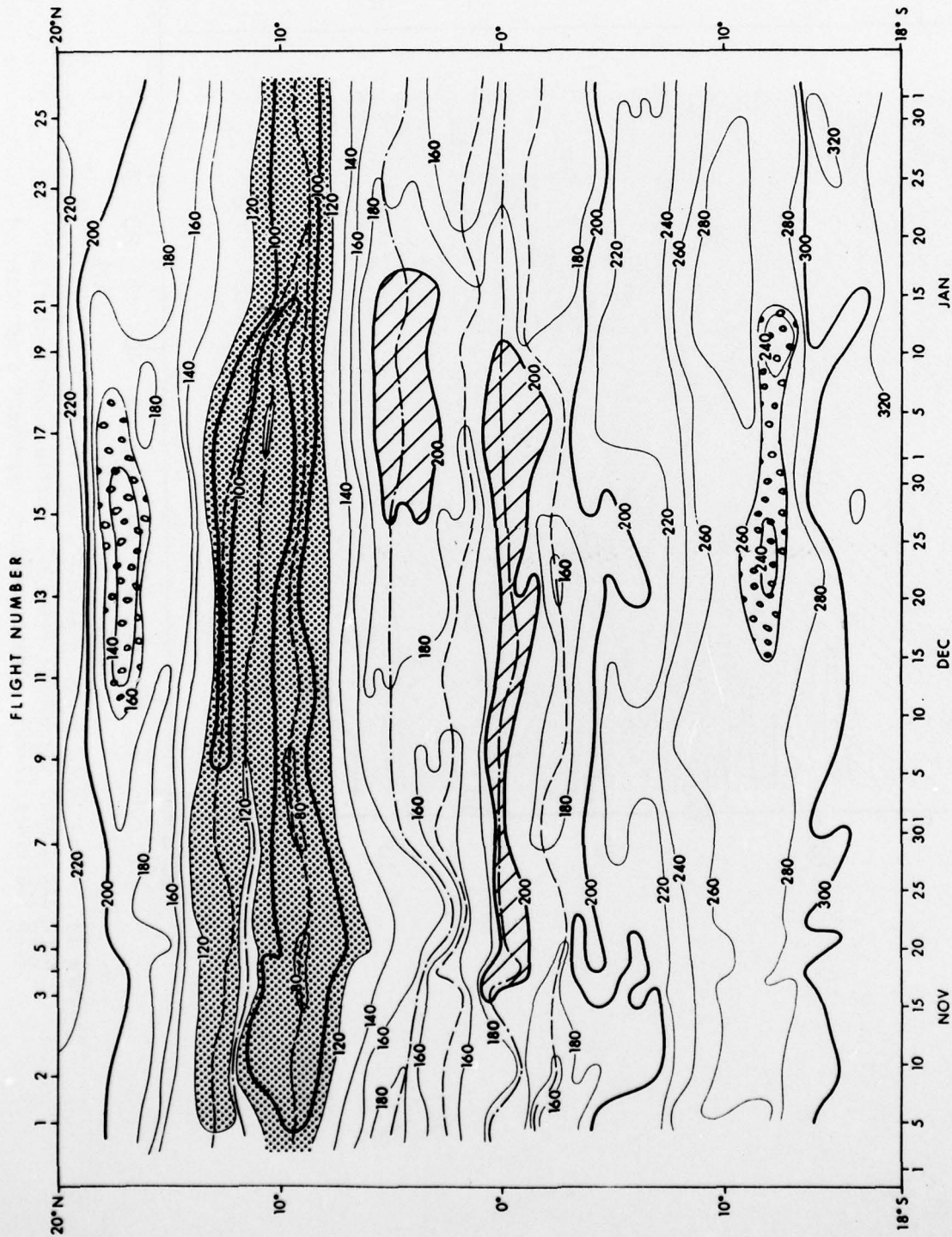


Figure 14. Depth of the 14°C isotherm in meters along 150°W collected using AXBTs from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 5 November 1977 to 30 January 1978 (Sections 1-16).

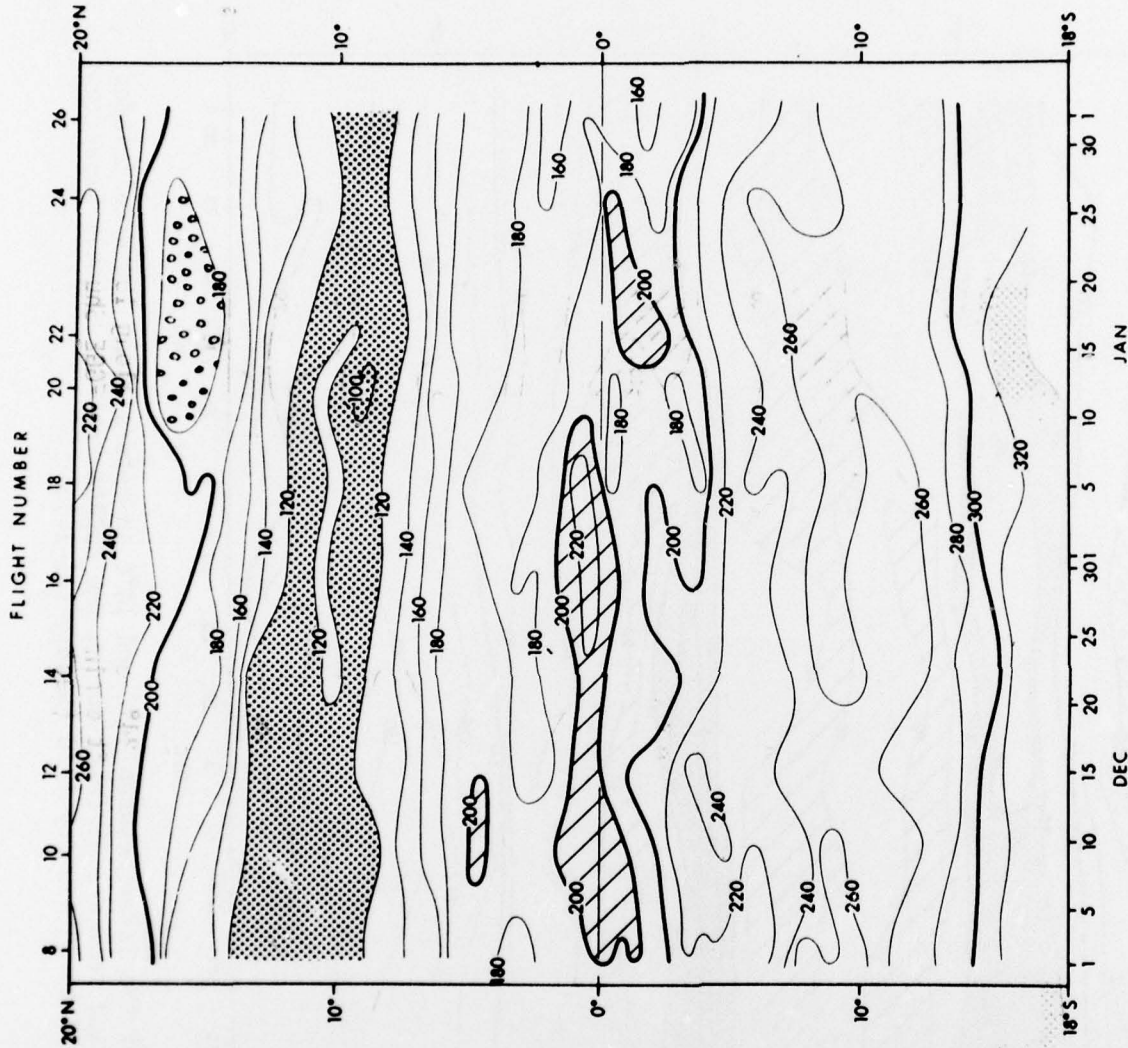


Figure 15. Depth of the 14°C isotherm in meters along 158°W collected using AXBTs from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 2 December 1977 to 1 February 1978 (Sections 17-26).



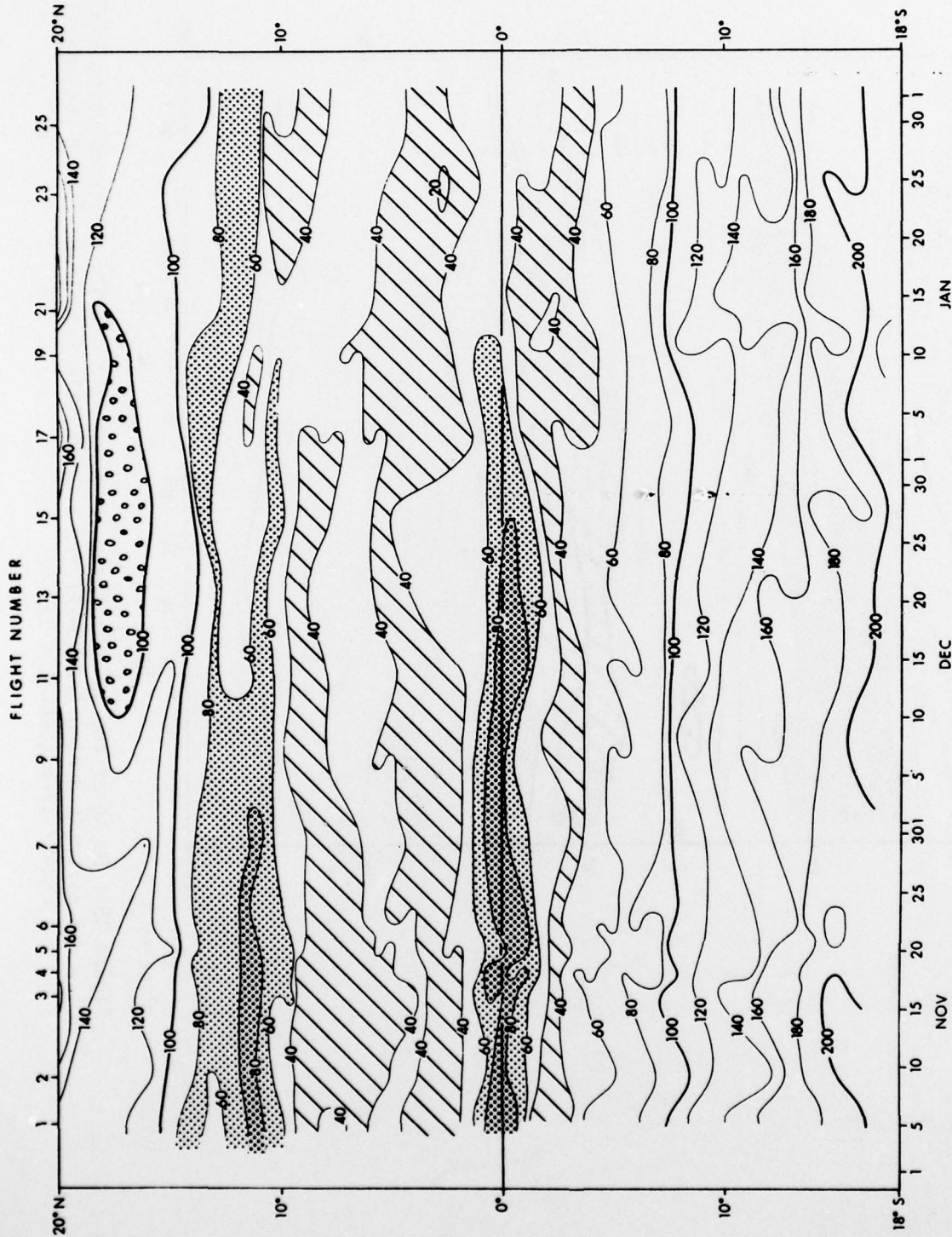


Figure 16. Thickness of the layer between 24°C and 14°C in meters along 150°W calculated using AXBTs collected from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 5 November 1977 to 30 January 1978 (Sections 1-16).

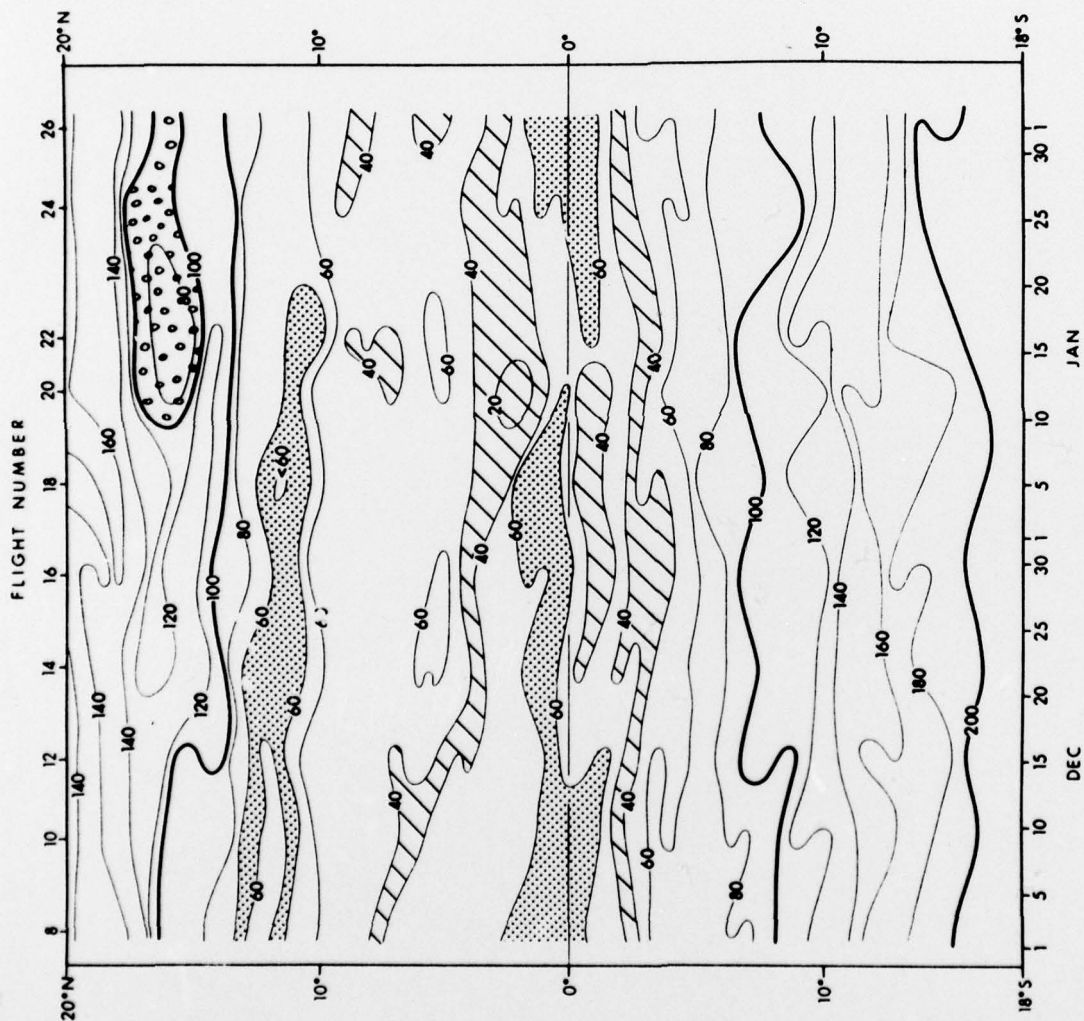


Figure 17. Thickness of the layer between 24°C and 14°C in meters along 158°W calculated using AXBTs collected from P-3 aircraft during the NORPAX Pre-FGGE Shuttle Experiment from 2 December 1977 to 1 February 1978 (Sections 17-26).